DOCUMENT RESUME

ED 183 830 CE 024 391

TITLE Military Curricula for Vocational & Technical Education. Refrigeration & Air Conditioning Specialist, Blocks I-II.
INSTITUTION Air Force Training Command, Sheppart AFB, Tex.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY Bureau of Occupational and Adult Education (DHEW/OE), Washington, D.C.
PUB DATE 25 Sep 74
NOTE 448p.; Small print in diagrams will not reproduce well. For related documents see CE 024 392-393.

EDRS PRICE MF01/PC18 Plus Postage.
DESCRIPTORS *Air Conditioning; *Air Conditioning Equipment; Behavioral Objectives; Course Descriptions; Curriculum Guides; *Electric Circuits; *Equipment Maintenance; Equipment Utilization; *Hand Tools; High Schools; Learning Activities; *Machine Tools; Postsecondary Education; Programed Instructional Materials; *Refrigeration; Refrigeration Mechanics; Study Guides; Textbooks; Trade and Industrial Education; Workbooks
IDENTIFIERS Military Curriculum Project

ABSTRACT

This plan of instruction, study guides, workbooks, and programmed texts for a secondary-postsecondary-level course in refrigeration and air conditioning are one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. It is the first section of a three-part course (see Note for other sections) intended to train students in identification, location, function, installation, operational checking, servicing, repair, and maintenance of refrigeration and air conditioning systems. Dealing specifically with the use of hand and special tools, refrigeration materials, and electrical principles, this section contains two blocks covering 93.5 hours of instruction: Fundamentals (3 lessons) and Electricity (3 lessons). The plan of instruction contains an outline of the teaching steps, criterion objectives, lesson duration, correlation of tasks with a training standard, and support materials and guidance. Student materials include three study guides with text information, objectives, review exercises, and references; three workbooks with performance exercises; and five programmed texts for individualized instruction. Commercial texts, military technical manuals, and audiovisual aids are suggested, but not provided. Materials may be adapted for individualized instruction, remedial work, or independent study. (YLB)

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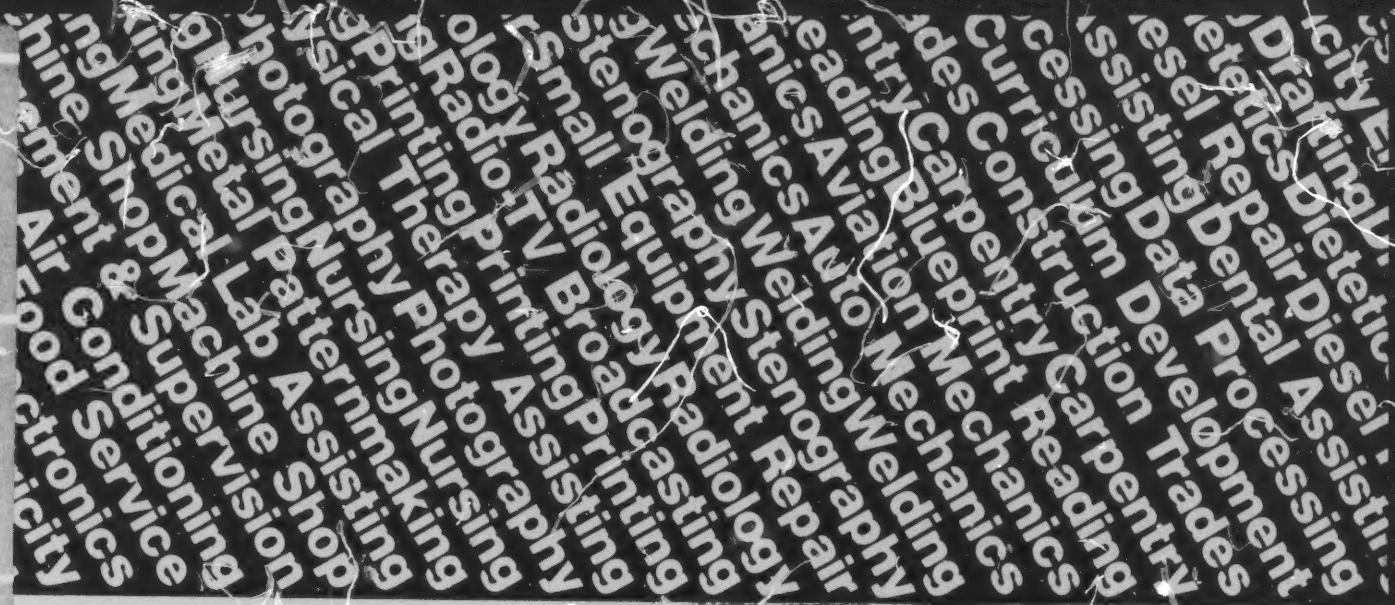
Diesel Repair Diesel
Dental Assisting
Data Processing
Curriculum Development
Construction Trades
Carpentry Carpentry
Blueprint Reading
Aviation Mechanics
Auto Mechanics
Welding Welding
Stenography Stenography
Small Equipment Repair
Radiology Radiology
Radio/TV Broadcasting
Printing Printing
Physical Therapy Assisting
Photography Photography
Nursing Nursing
Patternmaking
Medical Lab Assisting
Machine Shop
Management & Supervision
Air Conditioning
Food Service
Electronics
Electricity

Military Curricula for Vocational & Technical Education

#5
5114

REFRIGERATION & AIR CONDITIONING SPECIALIST
BLOCKS I-II

CE 024 391

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

REFRIGERATION & AIR CONDITIONING SPECIALIST

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Electrical Fundamentals - Programmed Text Page 369

REFRIGERATION AND AIR CONDITIONING SPECIALIST, BLOCKS I & II

Classroom Course

eveloped by:

United States Air Force

evelopment and
eview Dates:

September 25, 1974

Occupational Area:
Heating and Air Conditioning

Target Audiences:
Grades 11-adult

Print Pages:
446

Cost:
$9.00

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials:						Instructional Design:				Type of Instruction:	
	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Group Instruction:	Individualized:
			No. of pages									
Block I – *Fundamentals*			27									
Hand Tools, Special Tools, and Shop Equipment	•		•		•		•		•	*	•	
Refrigeration Lines, Fittings, and Tube Fabrication	•		•		•		•		•	*	•	
Soldering	•		•		•	*	•		•	*	•	
Block II – *Electricity*			77									
Electrical Principles and Circuits	•	•	•		•	*	•		•	*	•	•
Alternating Current Wiring Systems	•		•		•	*	•		•	*	•	
Electrical Troubleshooting	•	•	•		•	*	•		•	*	•	•

* Materials are recommended but not provided.

Expires July 1, 1978

Course Description:

This is the first section of a three-part course on refrigeration and air conditioning. The course trains students in identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. This section deals specifically with the use of hand and special tools, refrigeration materials, and electrical principles. It contains two blocks covering 93.5 hours of instruction.

Block I — *Fundamentals* contains three lessons and has 25.5 hours of instruction. The lessons on orientation and safety were deleted. The remaining lesson topics and respective hours follow:

Hand Tools, Special Tools, and Shop Equipment (3 hours)
Refrigeration Lines, Fittings and Tube Fabrication (6 hours)
Soldering (16.5 hours)

Block II — *Electricity* contains three lessons covering 68 hours of instruction.

Electrical Principles and Circuits (24 hours)
Alternating Current Wiring Systems (22 hours)
Electrical Troubleshooting (22 hours)

This section contains both teacher and student materials. Printed instructor materials include a plan of instruction detailing the teaching steps by units of instruction, criterion objectives, the duration of the lessons, correlation of tasks with a training standard, and support materials and guidance. Student materials include three study guides with text information, objectives, review exercises and references; three workbooks with performance exercises; and five programmed texts for individualized instruction.

Text information is provided in the student study guides, however, several commercial texts and military technical manuals are referenced. Audiovisual aids suggested for use in the entire three-part course include 15 films, 29 transparency sets and 29 charts. Much of this section contains introductory material that can be adapted for individualized instruction. This section could be used for remedial work or independent study for beginning students with little experience in the use of tools or the fundamentals of electricity.

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POI 3ABR54530
(PDS Code ATA)

PLAN OF INSTRUCTION
(Technical Training)

REFRIGERATION AND AIR CONDITIONING SPECIALIST

AIR TRAINING COMMAND

SHEPPARD TECHNICAL TRAINING CENTER

16 January 1976-Effective 17 March 1976 with class 760317

11-6

* see underscore in para 1 of Foreword, page i

DEPARTMENT OF THE AIR FORCE
USAF School of Applied Aerospace Sciences (ATC)
Sheppard Air Force Base, Texas 76311

PLAN OF INSTRUCTION 3ABR54530
(PDS Code ATA)
16 January 1976

FOREWORD

1. PURPOSE: This publication is the plan of instruction (POI) when the [illegible] shown on page A are bound into a single document. The POI prescribes the qualitative requirements for Course Number 3ABR54530, Refrigeration and Air Conditioning Specialist, in terms of criterion objectives and teaching steps presented by units of instruction and shows duration, correlation with the training standard, and support materials and guidance. When separated into units of instruction, it becomes Part I of the lesson plan. This POI was developed under the provisions of ATCR 50-5, Instructional System Development, and ATCR 52-7, Plans of Instruction and Lesson Plans.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is Group/Lock Step. The course trains airmen to perform duties prescribed in AFM 39-1 for Refrigeration and Air Conditioning Specialists, AFSC 54530. Training includes the use of AF publications and forms, and commercial manuals related to identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. The course also includes water analysis and conditioning. In addition, related training is provided on driver education, troop information program, commander's call/briefings, etc.

3. TRAINING EQUIPMENT. The number shown in parentheses after equipment listed as Training Equipment under SUPPORT MATERIALS AND GUIDANCE is the planned number of students assigned to each equipment unit.

4. REFERENCES. This plan of instruction is based on Specialty Training Standard, 54530/50/70, 18 April 1973, and Course Chart 3ABR54530, 15 January 1976.

FOR THE COMMANDER

LEONARD A. HAMILTON, Col, USAF
Chief, Dept of Civil Engineering Training

Supersedes Plan of Instruction 3ABR54530, 15 August 1973
OPR: Department of Civil Engineering Training
DISTRIBUTION: Listed on page A

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MODIFICATIONS

Pages 1-6 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-I-3, Hand Tools and Special Tools
WB 3ABR54530-I-3-P1, Identification and Selection of Hand Tools, Special Tools, Portable and Installed Shop Equipment
2TPT-3200-01, Common Hand Tools

Training Equipment
Trainer, Welding, Dual Type with Tool Drawer (2)
Power Grinder (12)
Power Drill (12)
Hand Tools (1)

Training Methods
Discussion/Demonstration (1.5 hrs)
Performance (1.5 hrs)

Instructional Guidance
Place adequate emphasis on use of drill stand. Students should always wear goggles when operating drill stand.

PLAN OF INSTRUCTION NO.	3ABR54530 11	DATE 16 January 1976	PAGE NO. 8

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

Refrigeration and Air Conditioning Specialist

BLOCK NUMBER: I

BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
3. Hand Tools, Special Tools, and Shop Equipment	3 (3/0) Day 1
a. Using the workbook, select and identify hand tools and special tools as to their type, size, application and care. STS: 5a, 5b, Meas: W, PC	(1.8/0)
(1) Types of hand tools and their application	
(2) Types of special tools	
(3) Care of hand and special tools	
(4) Safety precautions when using tools	
b. Using a drawing of a drill stand, identify the major components and list the safety precautions to be observed while operating it. STS: 5e Meas: W, PC	(1.2/0)
(1) Use and care of portable and installed shop equipment	
(2) Safety precautions when using shop equipment	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR54530	16 January 1976	7

ATC FORM 133 OCT 75 PREVIOUS EDITION IS OBSOLETE

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
I	Fundamentals

1 COURSE CONTENT	2 TIME
4. Refrigeration Lines, Fittings and Tube Fabrication	6 (6/0) Day 2
a. Given an assortment of refrigeration tubing, complete the workbook by identifying the tube by size and type. STS: 8a Meas: W, PC	(1/0)
(1) Types of copper tubing and their applications	
(2) Sizing copper tubing	
b. Using a ruler, tubing cutter, tubing bender, and a roll of copper tubing, measure, cut, and bend tubing as specified in the workbook. STS: 6d(5), 8b, 8c Meas: W, PC	(1.5/0)
(1) Tools for measuring cutting and bending	
(2) Procedures for cutting and bending copper tubing	
(a) Safety precautions	
(b) Cutting copper tubing	
(c) Bending copper tubing	
c. Using a ruler and an assortment of refrigeration fittings, identify each fitting by size and type as specified in the workbook. STS: 8d Meas: W, PC	(1.5/0)
(1) Selecting and identifying refrigeration fittings	
(2) Measurement of fittings	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR54530	16 January 1976	9

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

d. Using a ruler, tubing cutter, flaring kit and copper tubing, measure, cut, flare, and swage the tubing as specified by the workbook. STS: 6d(5), 8c Meas: W, PC (2/0)

(1) Tools used for flaring and swaging

(2) Flaring procedures

(3) Swaging procedures

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Material
SG 3ABR54530-I-4, Refrigeration Tubing, Fitting and Tube Fabrication
WB 3ABR54530-I-4-P1, Identifying Copper Tubing
WB 3ABR54530-I-4-P2, Cutting and Bending Copper Tubing
WB 3ABR54530-I-4-P3, Identifying Refrigeration Fittings
WB 3ABR54530-I-4-P4, Flaring and Swaging Copper Tubing

Training Equipment
Special Tools (1)
Refrigeration Lines (1)
Fittings (1)
Tube (1)

Training Methods
Discussion/Demonstration (2 hrs)
Performance (4 hrs)

Instructional Guidance
Place adequate emphasis on safety precautions involved when working with tube fabrication and tools.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
5. Soldering	16.5 (16.5/0) Days 3, 4, and 5
a. Using the welding trainer and the hydrocarbon torch, soft-solder a copper swage with at least 75% penetration, with no excess inside of joint. STS: 5e, 6c, 6d(1), 6d(5), 9a(1). Meas: W, PC	(3/0) Day 3
(1) Major parts of the hydrocarbon torch	
(2) Types of soft solder	
(3) Procedures for soft soldering	
(4) Inspection of soldered swage	
b. Using the welding trainer and the hydrocarbon torch, hard-solder a copper swage with at least 75% penetration, with no excess inside of joint. STS: 5e, 6c, 6d(1), 6d(2), 6d(5), 9a(2) Meas: W, PC	(3/0) Day 3
(1) Type of hard solder	
(2) Procedures for hard-soldering	
(3) Inspection of soldered swage	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR54530	16 January 1976	11

ATC FORM OCT 75 133 PREVIOUS EDITION IS OBSOLETE

c. Using the welding trainer and the hydrocarbon torch, aluminum-solder an aluminum swage with at least 75% penetration with no excess inside the joint. STS: 5e, 6c, 6d(1), 6d(2), 6d(5), 9a(3). Meas: W, PC

(3/0)
Day 4

(1) Type of aluminum solder

(2) Procedures for aluminum brazing

(3) Inspection of brazed swage

d. Using the welding trainer and the oxyacetylene torch, silver-solder a copper swage joint with at least 75% penetration with no excess inside the joint. STS: 5e, 6c, 6d(1), 6d(2), 6d(5), 9b Meas: W, PC

(7.5/0)
Days 4
and 5

(1) Major parts of the oxyacetylene torch

(2) Types of silver solder

(3) Procedures for silver-brazing with Sil-bond 45

(4) Inspection of brazed swage

(5) Procedures for brazing with Sil-foss

(6) Inspection of brazed joint

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-I-5, Soldering
WB 3ABR54530-I-5-P1, Soft Soldering
WB 3ABR54530-I-5-P2, Hard Soldering
WB 3ABR54530-I-5-P3, Aluminum Brazing
WB 3ABR54530-I-5-P4, Identifying Oxyacetylene Equipment
WB 3ABR54530-I-5-P5, Preparing Oxyacetylene Equipment for Use
WB 3ABR54530-I-5-P6, Silver Brazing
WB 3ABR54530-I-5-P7, Silver Brazing Using Sil-Foss

c. Using the welding trainer and the hydrocarbon torch, aluminum-solder an aluminum swage with at least 75% penetration with no excess inside the joint. STS: 5e, 6c, 6d(1), 6d(2), 6d(5), 9a(3). Meas: W, PC

(3/0)
Day 4

(1) Type of aluminum solder

(2) Procedures for aluminum brazing

(3) Inspection of brazed swage

d. Using the welding trainer and the oxyacetylene torch, silver-solder a copper swage joint with at least 75% penetration with no excess inside the joint. STS: 5e, 6c, 6d(1), 6d(2), 6d(5), 9b Meas: W, PC

(7.5/0)
Days 4 and 5

(1) Major parts of the oxyacetylene torch

(2) Types of silver solder

(3) Procedures for silver-brazing with Sil-bond 45

(4) Inspection of brazed swage

(5) Procedures for brazing with Sil-foss

(6) Inspection of brazed joint

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-I-5, Soldering
WB 3ABR54530-I-5-P1, Soft Soldering
WB 3ABR54530-I-5-P2, Hard Soldering
WB 3ABR54530-I-5-P3, Aluminum Brazing
WB 3ABR54530-I-5-P4, Identifying Oxyacetylene Equipment
WB 3ABR54530-I-5-P5, Preparing Oxyacetylene Equipment for Use
WB 3ABR54530-I-5-P6, Silver Brazing
WB 3ABR54530-I-5-P7, Silver Brazing Using Sil-Foss

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Audio Visual Aids
Charts, Set, Oxygen and Acetylene

Training Equipment
Tube Swaging Kit (1)
Trainer, Welding Dual Type (2)
Soldering Equipment (1)

Training Methods
Discussion/Demonstration (5 hrs)
Performance (11.5 hrs)

Multiple Instructor Requirement
Safety, Equipment, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions involved in the use of torches, soldering equipment, handling of oxygen, and acetylene cylinders; and the handling of hot metal.

MIR: Two instructors are required for 11.5 hours during student performance (4.25 hours in Day 3, 4.25 hours in Day 4, and 3 hours in Day 5).

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

6.	Related Training (identified in course chart)	10
7.	Measurement Test and Test Critique	1.5 (1.5/0) Day 5

STUDY GUIDE 3ABR54530-I-1, I-3 thru 5

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

FUNDAMENTALS

April 1975

SHEPPARD AIR FORCE BASE

11-6

Designed For ATC Course Use

DO NOT USE ON THE JOB

TABLE OF CONTENTS

Study Guides 3ABR54530-I

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I-1	Orientation and Civil Engineering Organization	April 1975	1
I-2	Safety (Use Common Study Guide--Published Separately)	January 1975	---
I-3	Hand Tools and Special Tools	April 1975	23
I-4	Refrigeration Tubing, Fittings, and Tubing Fabrication Soldering	April 1975	43
I-5	Soldering	April 1975	57

This supersedes SG 3ABR54530-I-1, I-3 thru 5, and WBs 3ABR54530-I-1-P1 thru 5-P6, September 1973.
Copies of the superseded publication may be used until the stock is exhausted.

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MODIFICATIONS

Pages 1-22 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

HANDTOOLS AND SPECIAL TOOLS

OBJECTIVE

This study guide will help you in becoming familiar with the identification, use and care of various hand and special tools.

INTRODUCTION

Few words have so many meanings as the word "tools." Each workman has certain tools which he uses in his work. These tools cover a range from such common things as screwdrivers and hammers to such uncommon things as "sky hooks" and "catheads." In this text, only those tools you will be using in your career field will be discussed, since these will be the most important to you.

Volumes have been written on the proper use of hand tools but the feeling still persists that they are so simple that no one need bother to point out the right and wrong ways of using them. In this text, we are going to outline the care, handling, and use of basic hand tools for your guidance and information. If you will follow the suggestions given, they will pay off for you and the Air Force.

A mechanic uses the tools in his tool kit almost every day. One of the marks of a good mechanic is the care he gives his tools. He prolongs their life and increases his efficiency and the quality of his work by keeping his tool box organized.

The check list of a good mechanic looks like this:

1. Keep tools as clean as possible when using them and be sure to clean them before putting them away.
2. Use each tool only for the purpose intended.
3. Have a special place in the tool box for each tool.
4. Keep every tool in excellent condition. Check tools regularly and replace worn or broken tools promptly.
5. Make an inventory of tools after each job to prevent leaving tools in ducts, fans, etc.
6. Keep junk and unnecessary tools out of the tool box.
7. Keep tool boxes securely locked and in a safe place when not in use.

TORQUING TOOLS

Screwdrivers and wrenches are commonly referred to as torquing tools.

Before studying torquing tools, the meaning of the work "torque" should be understood. It is a force that produces or tends to produce a rotating or twisting motion such as that shown in figure 1. Torque can be applied with any tool which is used to produce a twisting or turning motion. Too much torque will break bolts (figure 2), strip threads, or cause internal stress (strain the inside of the bolt) which weakens bolts. Technical Order 1-1A-8 contains charts which give the safe torque value that can be applied to different bolts and nuts. Torque can be figured by multiplying the length of the wrench handle times the pounds of force (push or pull) applied.

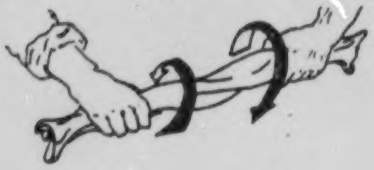


Figure 1. Torque

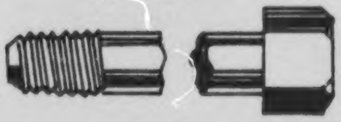


Figure 2. Overtorqued Bolt

If a wrench handle is six (6) inches from the center of the drive to the hand grip, applying a force of forty (40) pounds will produce 240-inch pounds of torque (6 inches x 40 lb = 240 inch lb). See figure 3 below.

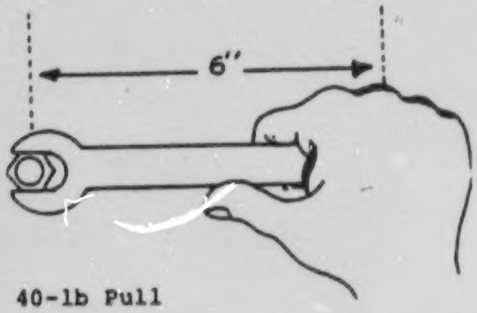


Figure 3. Torque - Length x Force

The smaller the opening in the wrench is, the shorter the overall length. This proportions the lever advantage of the wrench to the size of the bolt or stud. With a given amount of pull on a wrench, a short length will produce less twisting or torque, and will reduce the possibility of shearing or stripping the nut.

SCREWDRIVERS

There are several different types of screwdrivers. Phillips, Reed and Prince, and Common are types of screwdrivers which are in common use.

Each type is designed to fit a particular type scrw, as shown in figure 4. Within each type there are several sizes. The size of the screwdriver increases as the size of the screw increases.

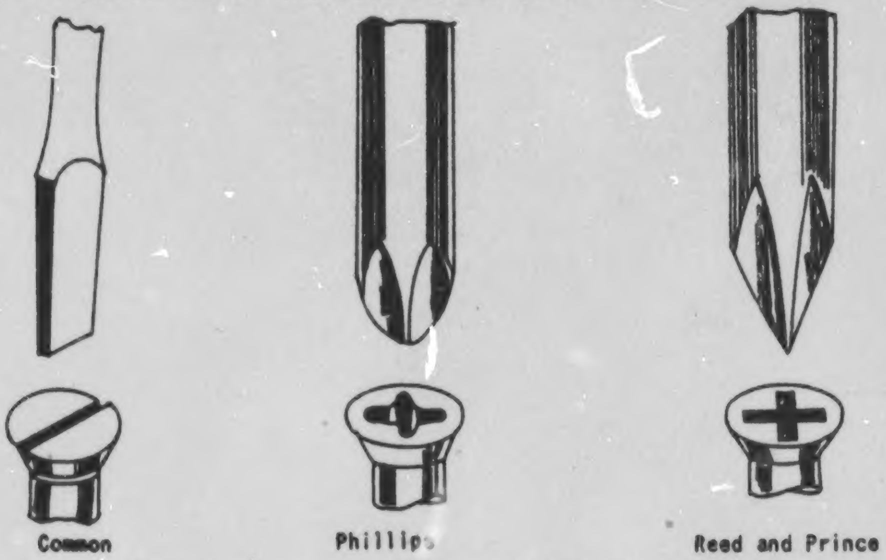


Figure 4. Screwdriver Bits and Screw Slots

COMMON SCREWDRIVER

The common screwdriver has a flat bit, the faces of the bit being almost parallel at the point.

Screwdrivers are usually identified by size according to the length of the blade and the width of the bit (see figure 5). Measure the screwdriver from the base of the handle to the tip of the bit. This gives the screwdriver size. Common sizes are 3", 4", 6", 8", 10", and 12".

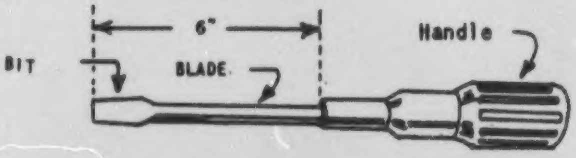


Figure 5. Size of Screwdriver

When using a screwdriver to apply torque, pressure should be exerted straight down on the handle as shown in figure 6. When selecting a screwdriver for use, select the largest bit that will fit the screw slot. There should never be less than 75 percent of the screw slot filled by the bit.

Too much emphasis cannot be placed on selecting a screwdriver that fits the screw slot. Figure 7 will aid you in selecting the correct size. A screwdriver of the correct size for the screw slot will prevent marking, breaking, or bending the tip of the blade, reduce the force required to keep the screwdriver in the slot, and prevent damage to screw slot. Remember, there is a properly sized screwdriver for every job.

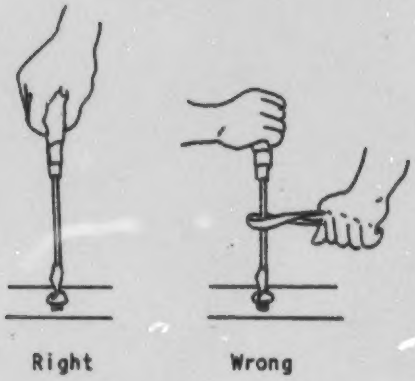

Right Wrong

Figure 6. Exert Pressure Downward

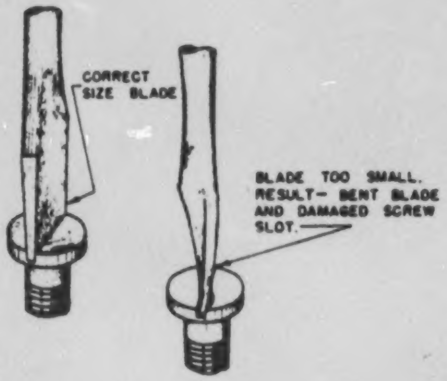

CORRECT SIZE BLADE
BLADE TOO SMALL. RESULT- BENT BLADE AND DAMAGED SCREW SLOT.

Figure 7. Bit Size

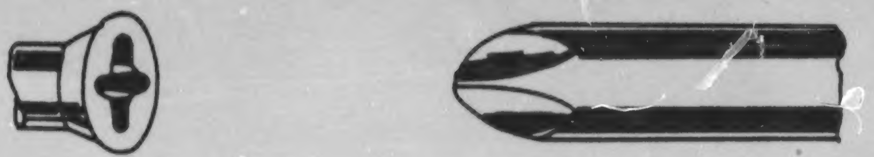
CROSSPOINT SCREWDRIVER

Crosspoint screwdrivers (see figure 8) are used on Reed and Prince and Phillips type screws. The crosspoint screwdriver is less likely to slip sideways and spoil the surrounding metal. However, they require more downward pressure than common screwdrivers. When selecting a crosspoint screwdriver for use, select the largest blade that will fit the screw slot. Crosspoint screwdriver size is determined in the same manner as a common screwdriver.

OFFSET SCREWDRIVER

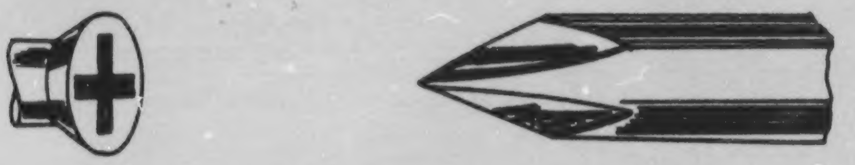
The offset screwdriver (see figure 9) has one blade bent at right angles to the shank and one blade forged in line with the shank. It is used in places that cannot be reached by a common screwdriver or where the swinging space is limited. When the swinging space is limited, you can change ends after each swing and thus work the screw in or out of the threaded hole. An offset screwdriver may have either a common or a crosspoint bit.

All screwdrivers with loose or cracked handles or with bent or broken blades should be turned in for replacement.



Phillips Screwhead

Phillips Screwdriver



Reed and Prince Screwhead

Reed and Prince Screwdriver

Figure 8. Crosspoint Screwdrivers

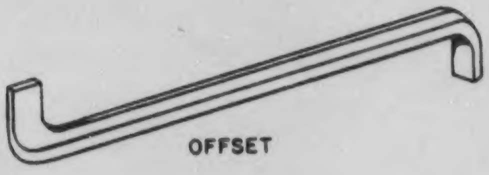


Figure 9. Offset Screwdriver

WRENCHES

Wrenches are tools used to turn bolts and nuts to tighten or loosen them. The common types of wrenches are the socket wrench, box end wrench, and open-end wrench.

SOCKET WRENCHES AND ATTACHMENTS

A socket wrench consists of a socket and handle (see figure 10). The best socket has a 12-point opening to fit a nut or the head of a bolt. It also contains a square opening to receive the drive handle. A socket can be used in close quarters because it needs to be turned only a short distance before it can be refitted on a nut or bolt. Sockets are the wrenches used, in conjunction with a torque wrench, to apply a specific amount of torque.

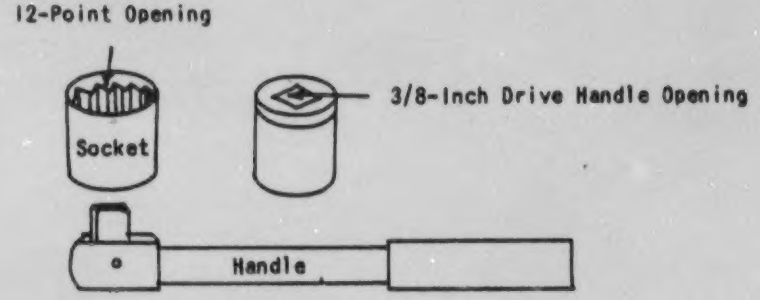


Figure 10. Socket and Handle

Ordinary sockets range in size from 1/4 to 3/4 inch. The drive handle openings are made to fit 1/4-, 3/8-, 1/2-, 3/4-, or 1-inch square drives. The size of a socket is stamped on the side of the socket.

The five types of handles for use with sockets are the ratchet handle, hinge handle, speed handle, sliding T-bar, and ell handle.

RATCHET HANDLE

The ratchet handle (see figure 11) will be used with a socket of the proper size to speed up the removal or replacement of nuts or bolts in close quarters. It can be ratcheted (swung) back and forth in an area too small for a complete swing of the wrench. This handle is not recommended for breaking loose or torquing nuts or bolts. Ratchet handles may be obtained with 1/4-, 3/8-, 1/2-, 3/4-, and 1-inch square drives.

HINGE HANDLE

Hinge handles (see figure 12) can be used with a socket to break loose nuts and bolts. Hold the handle vertically after loosening the bolts or nuts, and finger-twist them off. Hinge handles are designated by the square drive size and handle length.

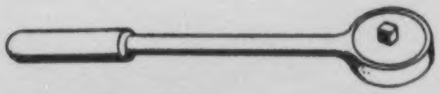


Figure 11. Ratchet Handle

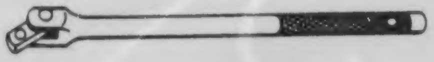


Figure 12. Hinge Handle

SPEED HANDLE

The speed handle (see figure 13) is used with a socket to remove or install nuts or bolts where very little force is required and there is plenty of room. This handle is not suitable for breaking loose or torquing a nut or bolt.

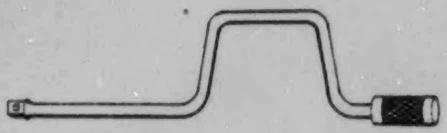


Figure 13. Speed Handle

SLIDING T-BAR HANDLE

The T-bar (see figure 14) is used on jobs that require a large amount of torque. The T-bar is often used with an extension bar, a universal joint, and a socket, as shown in figure 15, to spin nuts or bolts loose fast from a difficult place.

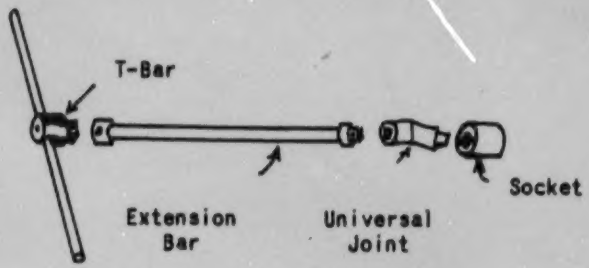


Figure 14. T-Bar Handle, Extension, Universal Joint, and Socket

The ell handle (figure 15) is used with a socket on jobs that require an extra large amount of torque.

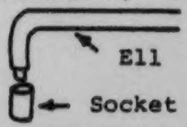


Figure 15. Ell Handle and Socket

EXTENSION

This bar is used to add reach to the handle as illustrated in figure 14. This bar comes in various lengths and enables the mechanic to get to bolts or nuts that could not normally be reached.

UNIVERSAL JOINTS

Universal joints (figure 16) are used so that the socket can be worked at an angle with the handle.

Selection of the type of handle to use with a socket depends upon the job to be performed.

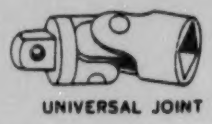


Figure 16. Universal Joint

One thing to keep in mind when using sockets is that they should never be overstressed. Always use a socket that is big enough for the job. A 3/8-inch square drive is not constructed to do the heavy work which should be performed with a 1/2- or 3/4-inch square drive.

BOX END WRENCHES

These wrenches are called box end because they box or completely surround the nut or bolt head. This wrench is a bar with a 12-point head on each end.

A box end can be used in close quarters to loosen or tighten a nut or bolt where a minimum handle travel of 30 degrees is possible. In tightening a nut or bolt, there is little chance of the wrench slipping off. It is slower than other types of wrenches in that each time the nut is turned the wrench has to be lifted and refitted to the head of the bolt.

The wrench size is stamped on the handle (see figure 17). Notice that the wrench ends are offset 15 degrees for hand clearance while using the wrench (figure 18).

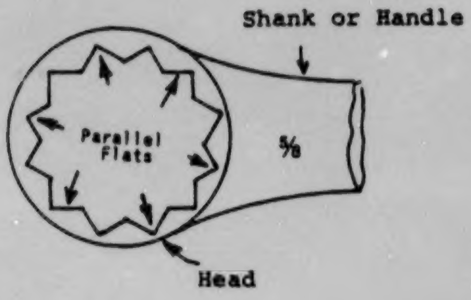


Figure 17. Box End Wrench

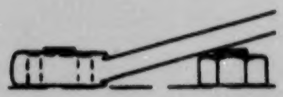


Figure 18. 15° Offset

OPEN END WRENCHES

Solid nonadjustable wrenches with openings in each end are called open-end wrenches.

The size of the openings between the jaws determines the size of the wrench. This means the distance across the flats and not the bolt diameter.

As you look at the open-end wrenches, notice that the head and openings are at a 15-degree angle to the shank (see figure 19). This offset makes it easier to work in close quarters.

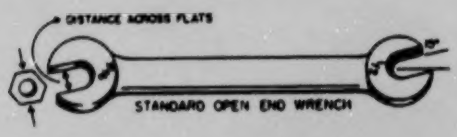


Figure 19. Open-End Wrench

An elementary trick is that of "flopping" the wrench after every stroke, as shown in figure 20 - turning it so the other face is down and the angle of the head is reversed to fit the next two flats of the hex nut. This makes it much easier to loosen or tighten a nut. Be sure the wrench fits the nut. A wrench that is too large will round off the nut. Always pull on the wrench, if possible.

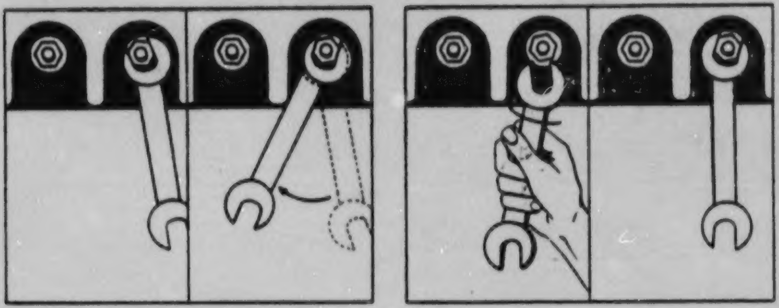


Figure 20. Use of Open-End Wrench

Adjustable Jaw. The adjustable jaw wrench is similar to the open-end wrench, except that one jaw is moveable, enabling a single wrench to be used on several sizes of nuts or bolts (see figure 21). The size of the wrench is determined by the total length. Always remember to close the jaws tightly against the nut or bolt before starting work. If this is not done, the nut or bolt will be damaged by the jaws.

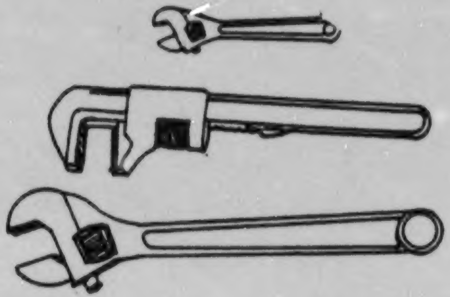


Figure 21. Adjustable Jaw Wrenches

Pipe. Pipe wrenches are used for turning pipe, round rods, or smooth fittings which do not offer a gripping surface for other types of wrenches (see figure 22). However, since the jaws have teeth which can damage the work, the adjustable strap wrench should be used if mars are objectionable.

Allen. Allen wrenches are merely six-sided bars bent into the shape of an "L." They are used to turn internal wrenching bolts and screws (see figure 23).

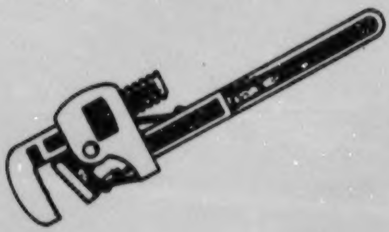


Figure 22. Pipe Wrench

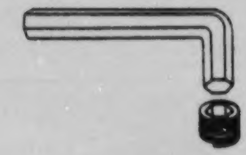


Figure 23. Allen Wrench Application

In deciding which is the best wrench to use, study the job to be done and consider the working space. Space and conveninece greatly dictate the type of wrench you will use. Box end or socket wrenches are generally considered first choice wrenches because they are less apt to slip.

26

CLEANING AND CARE OF WRENCHES

Wash grease and dirt from wrenches with cleaning solvent. Wipe dry with a clean dry cloth. Scour rust from wrenches with crocus cloth or aluminum oxide abrasive cloth. Apply a thin coat of oil to hand tools which show a tendency to rust.

TORQUE WRENCHES

Most mechanics have a tendency to overtorque. That is why torque wrenches were invented. A torque wrench enables the mechanic to tighten a nut or bolt with exactly the proper amount of torque. If a nut is left loose, it does not hold securely. If it is too tight, it may break the bolt, strip the threads, or put unnecessary strain on the parts being held together. The torque wrench indicates to the mechanic when the preselected torque value is attained.

Torque wrenches should be tested for accuracy at least once a month or as often as usage requires. After each test, torque wrenches are banded with a strip of color tape approximately 1/2 inch wide, containing the date (month and year) plainly marked thereon. The location of this tape is shown in figure 24. Torque wrenches are classified as a special tool, therefore are not issued in tool boxes. They may be checked out from a central point in the orgainization to which you are assigned.

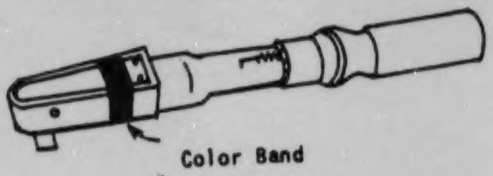


Figure 24. Torque Indicating Wrench

HAMMERS

The Ball-Peen hammer (see figure 25) is often used by the mechanic to shape soft metal with the peen end and hammer harder metals with the face. It is commonly used for driving chisels.

This plastic hammer (see figure 26) is used when working with materials which are soft enough to be damaged by using other types of hammers. This hammer is not used on nails, chisels, or pointed metal objects.

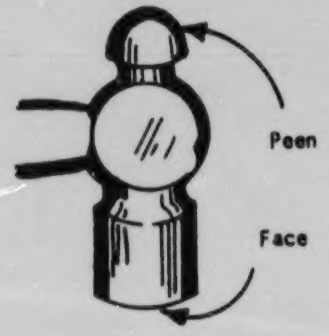


Figure 25. Ball-Peen Hammer

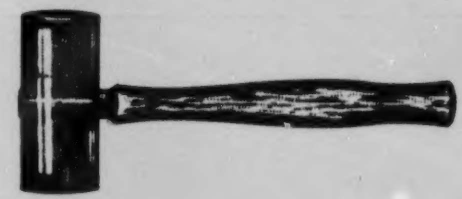


Figure 26. Plastic Hammer

Do not grip near the hammer head because this reduces the force of the blow. Grip the handle close to the end and strike the object with the full face of the hammer as illustrated in figure 27. Hammers with cracked, broken, or loose handles or a damaged face should be turned into supply for replacement.

PLIERS

Pliers of many types are manufactured for specilalized uses. However, some types have such a wide application that they are found in almost every mechanic's tool box. These are the diagonal cutting (dikes), long nose, and combination slip-joint pliers. Pliers are used when the grip of the hand is not enough to do the job and holding is necessary. Pliers are holding tools and should never be used as torquing tools.

Diagonal cutting pliers (figure 28) are used for cutting wire, removing cotter pins, and spreading split ends of cotter pins after the pin has been inserted. When cutting cotter pins, cup your hand or lay a rag over the pins to prevent the loose ends from flying into your face.

Long nose pliers (figure 29) are used to reach where fingers cannot or bend small pieces of metal to the desired shape.

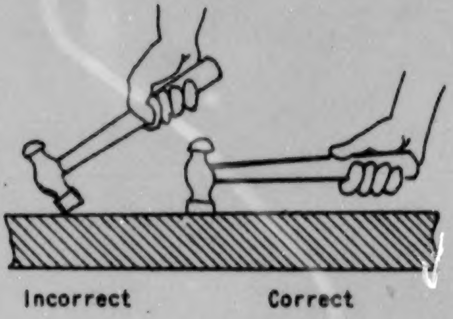


Figure 27. Use of Hammer

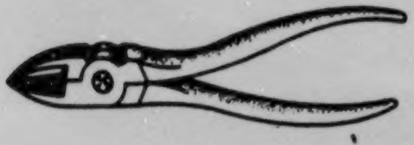


Figure 28. Diagonal Cutting Pliers

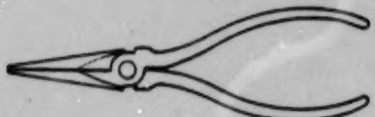


Figure 29. Long Nose

The combination slip joint pliers (figure 30) are more widely used than any other type. They are used for holding stock, twisting and cutting wire, and holding hot or cold metal.

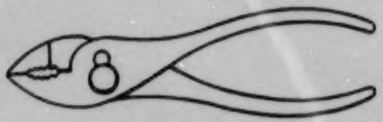


Figure 30. Combination Slip-Joint Pliers

Pliers may be cleaned with a prescribed cleaning solvent, brushed and wiped clean with a clean cloth. Lubricate pivot points with one or two drops of oil. If jaws of pliers are worn, replace with a serviceable pair. The size of pliers is determined by their overall length.

SHEARS

Shears are used for cutting sheet metal of various kinds. Figure 31 illustrates several commonly used shears. Shears with curved blades are convenient for making curved cuts. Scroll pivoter snips turn easily and follow irregular line readily. Bench shears are used for cutting metal of 16-gage or lighter.

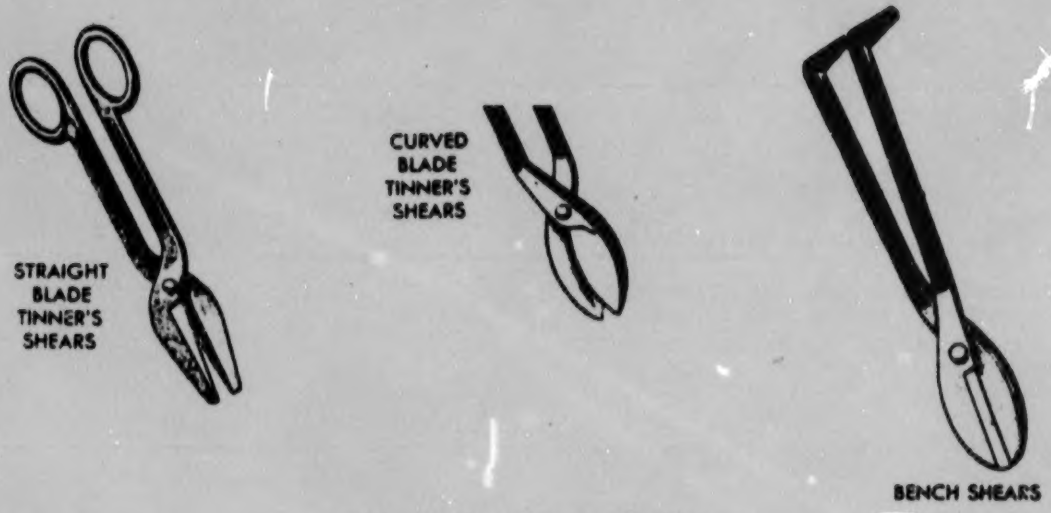

STRAIGHT BLADE TINNER'S SHEARS
CURVED BLADE TINNER'S SHEARS
BENCH SHEARS

Figure 31. Types of Shears

COLD CHISELS

Cold chisels are tools used for chipping or cutting cold metal by hand before its surface has been filed to a fit. Cold chisels are made of a good grade of tool steel, hardened at the point and sharpened to a cutting edge. Chisels are driven with a hammer. They will cut any metal softer than they are (in general, any metal that can be cut with a file). Figure 32 shows several types of cold chisels.

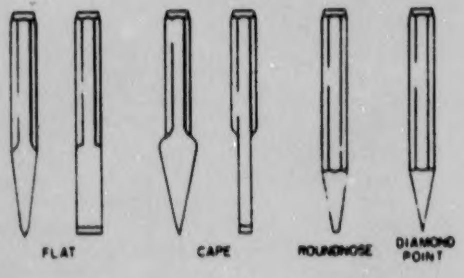

FLAT
CAPE
ROUNDNOSE
DIAMOND POINT

Figure 32. Commonly Used Cold Chisels

Chisels are classified according to the shape of their point; the most common shapes are the flat, cape, round-nose, and diamond point. Best results will be obtained if a type of cold chisel is selected that is designed for the particular work to be done.

Flat chisels are used for cutting sheet metal. Cape chisels are used to cut grooves, slots, and keyways. Round-nose chisels cut round grooves and diamond-point chisels are used to cut V-shaped grooves.

STOCK-HEAD SQUARE

The Stock-Head square set will be used by you more than any other layout tool. It has four parts. They are a graduated steel blade, a stock head, level, and scriber (see figure 33).

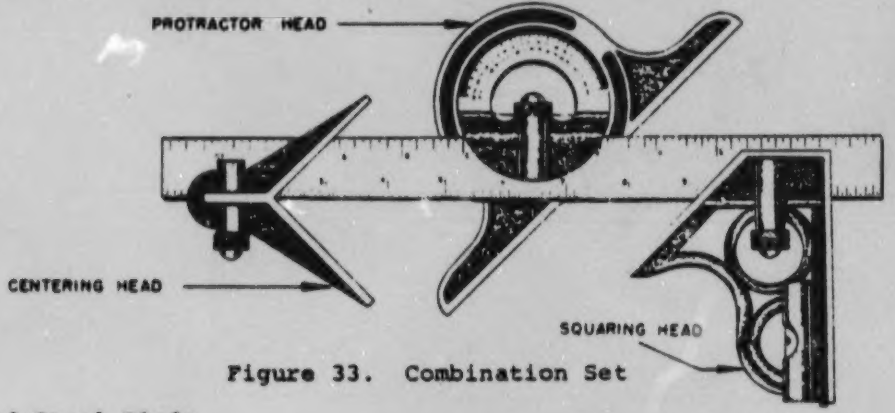


Figure 33. Combination Set

Graduated Steel Blade

The blade is laid off in inches. The inches are then divided into 1/2, 1/4, 1/8, 1/16, 1/32, and 1/64 of an inch.

The blade should not be allowed to get wet, and it should be kept lightly oiled to prevent rust. If it is dropped or thrown among other tools, it may be damaged and, therefore, hard to read.

This stock head when used with the graduate blade, will enable you to "square" stock which is to be cut. It may also be used to lay off 45- or 90-degree angles (see figure 34) and to check for level. The scriber is used to mark metal.

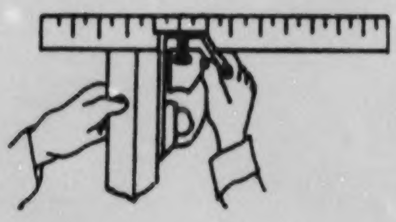


Figure 34. Checking for Squareness

Center Punch

After the exact spot to be drilled has been marked, the center punch and a ball peen hammer are used to make a slight hole or dent in which to start the drill (see figure 35).

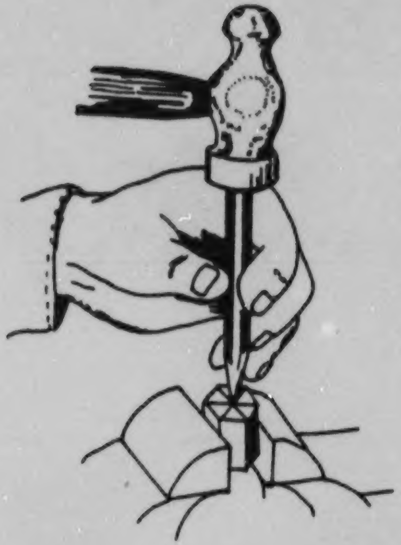


Figure 35. Center Punching

HACKSAWS

Hacksaws are used for cutting metals in much the same way as a carpenter's saw is used to cut wood.

Correct Use of Hacksaw

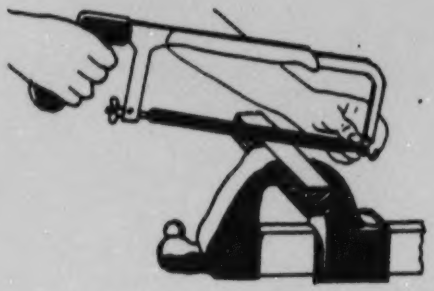


Figure 36. Correct Use of Hacksaw

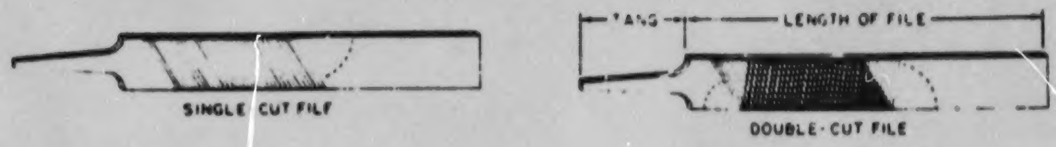
The hacksaw should be held firmly to prevent blade from "chattering" and twisting. It must also be held at such an angle that at least two teeth will be cutting at all times (see figure 36). The cut should be started with a light, steady, forward stroke. At the end of stroke, pressure should be released and the blade drawn straight back. After the first few strokes, the stroke should be as long as the hacksaw frame will permit, and no pressure applied on the back stroke. Speed should be held down to 40 or 50 strokes per minute, and never be more than 60 per minute. Just before the cut is finished, pressure should be relieved from the hacksaw and the rapidity of strokes decreased.

FILES

Files are used for cutting, smoothing, or removing small amounts of metal.

Types of Files

Files are made with single cut or double cut teeth. Single cut files have only one set of teeth in parallel rows. Double cut files have two sets of teeth cut at an angle to each other, forming diamond-shaped teeth, which cut faster than single cut files (see figure 37).


TANG
LENGTH OF FILE
SINGLE CUT FILE
DOUBLE-CUT FILE

Single Cut

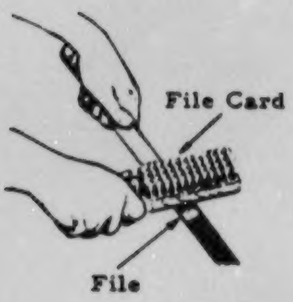
Double Cut

Figure 37. Single Cut and Double Cut Files

The file should always have a tight-fitting handle, or the person using it may be injured. If the file becomes clogged with metal particles, it will not cut but will scratch and mar the work. It may be cleaned with a metal pick, or with a file card which is a form of stiff wire brush (see figure 38).

Hand-Operated Drill

Hand-operated drills are used where the work cannot be taken to a shop, or when there is no power-driven drill. Three common hand-operated drills are known as the hand drill (egg beater), the breast drill, and the brace (see figure 39).


File Card
File

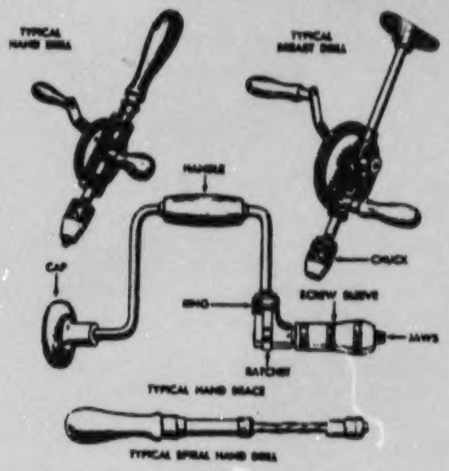

TYPICAL HAND DRILL
TYPICAL BREAST DRILL
HANDLE
CAP
CHUCK
SCREW SLEEVE
JAWS
RATCHET
TYPICAL HAND BRACE
TYPICAL SPIRAL HAND DRILL

Figure 38. Cleaning a File with File Card

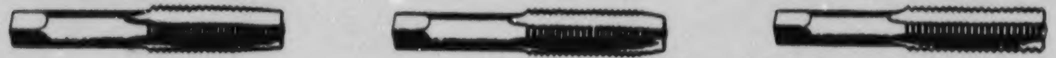
Figure 39. Hand-Operated Drills

TAPS

Taps are used to cut inside threads in drilled holes or a cylinder.

Kinds of Taps

The three kinds of taps are taper tap, plug tap, and bottoming tap (see figure 40).



Taper Tap

Plug Tap

Bottoming Tap

Figure 40. Three Kinds of Taps

The taper tap is used to start all inside threads, and it may also be used to finish threading when the drill hole goes all the way through the work. The plug tap is used where one end of the hold is closed. The bottoming tap is used to cut a full thread to the bottom of a closed hole. Neither the plug nor bottoming tap should ever be used to start a thread.

Proper Use of Taps

The correct size tap must be used to thread a certain size hole, or the threads may be cut too deep or too shallow. A table of tap sizes and matching drill sizes should be used for reference.

It is very important that the tap be started straight and kept straight. Taps, especially small ones, are easily broken if bent or strained. After the tap starts to cut or "bite," no pressure is applied, because its threads will pull it through at the proper rate. When cutting threads in aluminum, a drop of lard oil and kerosene on the cutting edge protects the tap from damage and results in a cleaner thread.

Extreme caution should be used when removing a tap from a hole after the threads are cut. Any side movment may damage the tap or the threads.

If a tap does break while it is being used, it can be removed from the hole with a small blunt cold chisel or a punch. The tap will usually start backing out when the chisel or punch is struck lightly with a ball-peen hammer. Once the broken tap is started turning, it can be removed with a tap extractor. If there is no extractor; the broken tap may be backed all the way out with the chisel or the punch (see figure 41).

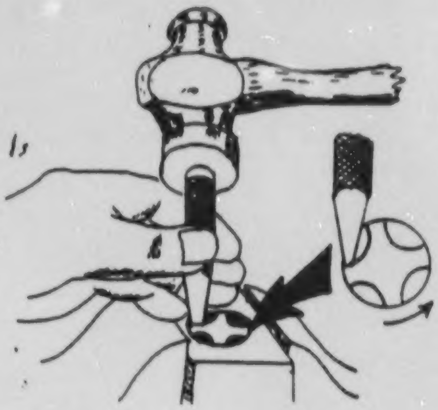


Figure 41. Removing Broken Tap with a Punch

ELECTRICAL DRILL

The process of drilling holes in metal with an electric drill is similar to drilling by hand except that the power for turning the drill is furnished by an electric motor rather than by the operator. Figure 42 shows a popular type electric drill. Notice that it is equipped with a pistol grip-type handle. Some have spade type handles, and the larger electric drills have two handles so they can be held with both hands while drilling.

When drilling a hole, the cutting is done by a drill bit made either of carbon steel or a special metal for high-speed work. Before starting to drill a hole, the exact center should be marked and punched with a center punch; this keeps the bit from creeping away from the desired hole location. Next, the drill should be started by placing the point of the bit to the punched spot and applying pressure. After the bit has just be begun to cut, it should be lifted from the work to be sure the hole is started in the exact location. When drilling the hole, the bit should always be held at the right angle to the work, and enough pressure applied to keep the bit cutting at all times. Just before drilling through a piece of metal, the pressure should be eased to prevent breaking the bit. After the bit has gone through the metal, it should be withdrawn with the drill running.

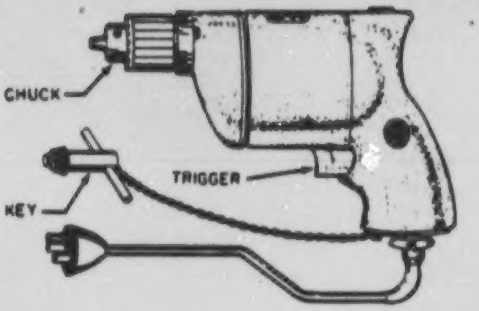


Figure 42. Electric Drill

Geared Chuck

Ordinarily, straight shank drill bits are used in both the hand-operated electric drill and the electric drill stand. These bits are secured in a key-type geared chuck (see figure 43). The geared chuck automatically centers the drill shank. Usually, the chuck is matched with the drill so that the chuck will open only wide enough to receive the maximum size drill for the motor. For example, a 1/4" electric drill will have a chuck which will take up to a 1/4" drill bit.

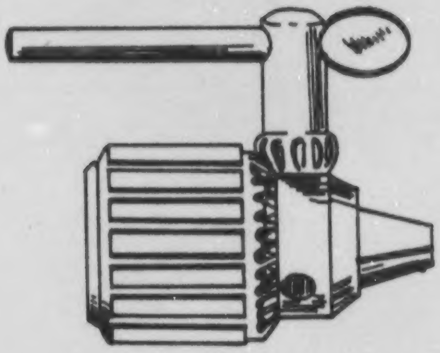


Figure 43. Geared Chuck

DRILL STAND

A drill stand (see figure 44) aids in accurately locating and maintaining the direction of a hole to be drilled, as well as providing the operator with an easy control for feeding the drill into the work. A lever is provided on the stand so the operator can feed the drill into the work with very heavy or light pressure. When using the drill stand, care must be used in securing or holding the work while drilling so that it does not move around and injure the operator.

BENCH GRINDER

Figure 45 shows a common type of bench grinder frequently used in refrigeration shops for hand-grinding operations. Common use for such a grinder is to sharpen chisels, reface screwdrivers, grind drills, remove excess metal from work, and smooth metal surfaces.

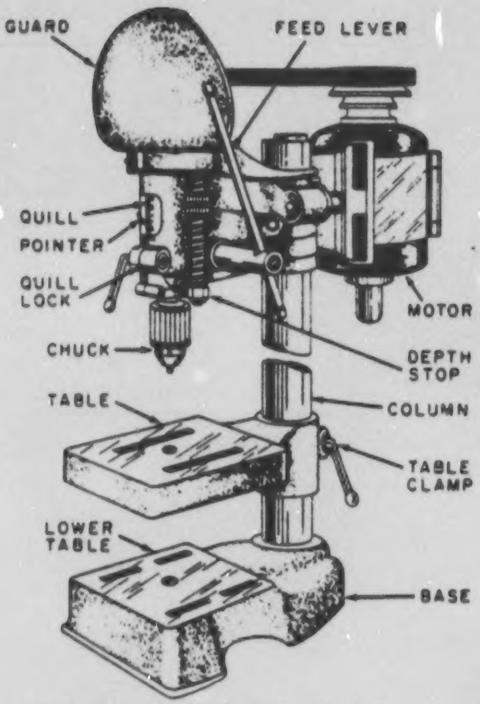


Figure 44. Drill Stand

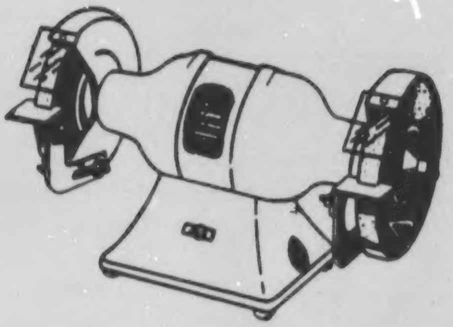


Figure 45. Bench Grinder

When using a grinder, the work should be held firmly at the correct angle on the rests provided and fed into the wheel with enough pressure to remove the desired amount of metal without generating too much heat. Metal to be ground should be fed against the wheel with both hands. The hand should never come within three inches of the wheel.

Before using a bench grinder, be sure the wheels are firmly secured to the spindles by the flange nuts and that the work rests are tight. Clear goggles must always be worn, even if eye shields are attached to the grinder. Keep in mind that it is unsafe to use a grinder without wheel guards. Also remember that it is easy to run your thumb or finger into the wheel. Wheel rest guards should be adjusted to within 1/8 inch of the grinding wheel.

SUMMARY

There are many types of hand and measuring tools with which you will perform your job. Some of these tools are the screwdriver, hammer, wrenches, chisels, and pliers. Each tool has its own particular application and must be used for that purpose only.

Modern equipment would be useless if accurate measurement and adjustment could not be made. In your career field, frequent use of measuring tools, such as rules, and torque wrenches, will be necessary.

Tools must be clean. Care must be taken to use the proper type and size tool for a particular job. Tools should be stored properly so they will not be damaged while not in use.

Remember, regardless of the type of job to be done, you must select and correctly use the proper tools in order to do your work quickly and accurately.

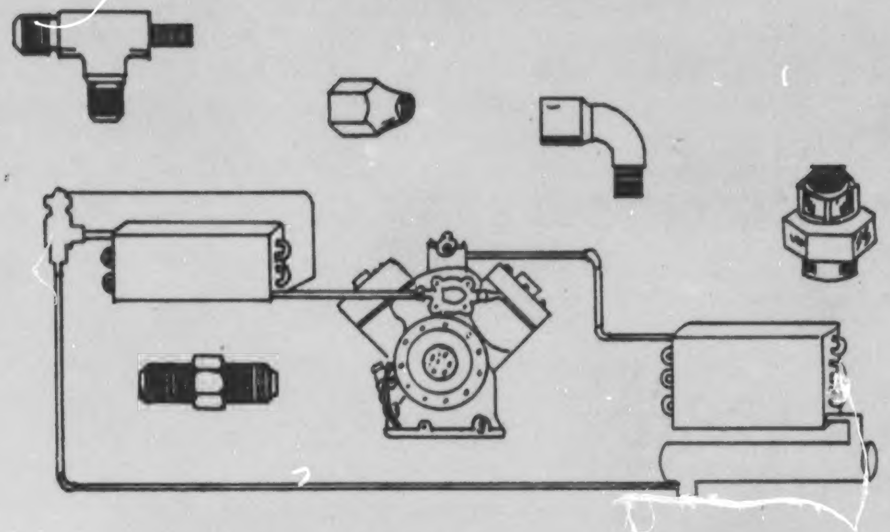
QUESTIONS

1. What is the meaning of "torque"?
2. What are four types of wrench handles designed for use with sockets?
3. What type of pliers are usually used for cutting wire?
4. Why must a screwdriver be held firmly against the screw slot?
5. Why is a pipe wrench suitable for turning pipe or round rods and not suitable for use on nuts and bolts?
6. To what fractional part of an inch are most rules graduated?
7. Why should a spot be marked with a center punch before drilling a hole?
8. When should a drill stand be used?
9. What precautions must be taken before using a bench grinder?
10. Wheel rest guards must be adjusted how close to the grinder wheel?

REFERENCES

1. TO 32-1-101, Maintenance and Care of Hand Tools
2. TO 32-1-151, Hand, Measuring, and Power Tools

REFRIGERATION TUBING, FITTINGS, AND TUBING FABRICATION



OBJECTIVE

To help you in learning:

- The types and characteristics of copper tubing
- The types and purpose of refrigeration fittings
- Tube fabrication

INTRODUCTION

Tube and pipe are used to transfer liquids and gases throughout refrigeration and equipment cooling systems. Some of these lines must withstand pressures up to 500 p.s.i., and others must withstand as much as 29 inches of vacuum.

When installing copper tubing, select a path that requires at least one bend. This is to help eliminate work-hardening caused by vibration and to allow for expansion and contraction due to temperature changes.

Refrigeration work requires cutting, bending, swaging and flaring of tubing. The serviceman's success depends to a great extent upon his skill in performing these operations accurately.

COPPER TUBING

The ease of handling and high heat conductivity make copper tubing highly desirable for use in refrigeration, plumbing, and heating installations.

Although copper tubing is in wide use, there is an unusual amount of confusion concerning its terminology and use. People who have handled and used copper tubing and fittings for years still make mistakes concerning the sizes and application of the different types. To correctly identify copper tubing and fittings, you must consider letters such as "K," "L", and "M" and terms such as soft drawn, hard temper, hard drawn, annealed and dehydrated. Annealing is the process of heating, then slowly cooling the tubing, resulting in the tubing being soft.

Types of Tubing

Type "K" has the thickest wall. It is normally used in steam heating and high pressure systems. When using this type tubing, you must remember that outside diameters remain constant as the wall thickness increases and inside diameters decrease. This may require using the next larger size to accommodate the required liquid or vapor.

Type "L" is used in refrigeration systems in sizes above 3/4 inch. Soft-tempered type "L" tubing is used to make continuous coils because it is so easily bent. On some installations this type tubing is used to connect a remote condensing unit to the evaporator. The ease of bending eliminates cutting and soldering. This allows installation time to be reduced to a minimum but doesn't make a very attractive system. Hard tempered type "L" is used for mains, herders, and risers and should be used in any area where the tubing might become damaged. The use of hard tempered tubing and soldered fittings makes very attractive installations and should be used where appearance is a factor.

Type "M" tubing has a thin wall and is suitable for low pressure work only. It has been widely used for sanitary drainage and may be used for interior water supply in some areas. This type of tubing is manufactured in hard temper only and in sizes 3/8 inch O.D. and above.

Type "M" tubing should never be used in the refrigeration system.

Type DWV tubing has the thinnest wall of all. It is only recommended for installations without pressure such as drainage, waste, and vents. About the only place where the refrigeration serviceman can utilize this type of tubing is in condensate water disposal.

Type "refrigeration service" is manufactured specifically for use in the refrigeration industry. The wall thickness is somewhere between types "L" and "M". This type of tubing is manufactured only in sizes 7/8 inch and under. It is furnished in soft temper only and is packed in 50-foot rolls. The tubing is cleaned, dehydrated, sealed, and annealed at the factory. The use of this special refrigeration tubing helps eliminate problems of moisture and foreign particles in the refrigeration system.

Commercial tube cannot rightly be called a type. This term is used to refer to any copper tube made to a customer's specification rather than standard specification. Commercial tube is used in prefabricated evaporators, condensers, and packaged refrigeration units. It serves very satisfactorily as long as the manufacturer makes sure the tubing will withstand the pressures and temperatures that the finished product will be expected to handle.

Refrigeration service people should never use commercial tube unless they are very sure of the pressure and temperature range.

Temper

When speaking of "K," "L," and "M" tubing, there is some tendency to talk about "soft drawn," "quarter-hard," "half-hard," and "full-hard." However, for all practical purposes, these types of copper tubing are either hard or soft; the in-between tempers are not significant to the serviceman. Remember, refrigeration service tubing is always soft drawn.

Recommended working pressures for hard and soft tubing in a given size are identical. The fact that soft tubing can be bent easily gives a false impression that it is weaker.

Color Code

As an aid in reducing mistakes as to the type of copper tubing, manufacturers are now color-coding all standard sizes of copper tubing. In some cases, the usual identifying words will be in color; in other cases, a continuous colored strip appears on the tubing. In most cases, coils of refrigeration service tubing are identified by the color of the carton.

The colors adopted by the Copper and Brass Research Association are:

Type K - green
Type L - blue
Type M - red
Type DWV - yellow
Type Refrigeration Service - crimson

ALUMINUM

High heat conductivity and light weight makes aluminum tubing widely used in the manufacture of evaporators for domestic (household) refrigerators.

STEEL

Strength and high heat conductivity is the reason steel has become the prime metal used in condensers for domestic refrigerators. As most domestic refrigerators have the condensers mounted on the backside, the condenser tubing is prone to be bent or mashed in the movement of the refrigerator. The introduction of steel in the manufacture of condensers has reduced this problem.

Black Iron

Black iron is used as the metal for refrigerant lines in systems employing ammonia as the refrigerant. Ammonia will corrode copper tubing.

Ordering Tubing and Fittings

One of the most confusing things about using copper tubing is the fact that plumbers use I.D. sizes and refrigeration people use O.D. sizes. If a plumber orders 3/8-inch tubing, he expects to get tubing with a 3/8-inch I.D. Refrigeration people ordering 1/2-inch tubing will get the same size. That is to say, 3/8-inch I.D. tubing and 1/2-inch O.D. tubing are the same size.

It is very obvious when ordering tubing that you must indicate whether you want an I.D. or O.D. size.

The problem becomes even more involved when fittings are ordered. Many wholesalers list fittings by I.D. size only. When refrigeration people order fittings, the supplier converts the order to the appropriate size. However, very often the purchaser has already converted in his own mind and has ordered fittings based on his own tubing size. Not realizing this, the supplier coverts again and the refrigeration man gets the wrong size.

This is a bad situation but we cannot change it so we must live with it. The only thing that can be done is to make sure our order clearly identifies the tubing as to type, temper, use, and whether the size is I.D. or O.D.

A typical order for refrigeration tubing should read:

> Tubing - copper, 1/2 inch O.D., annealed, dehydrated, and sealed. In 50-ft roll for refrigeration work.

For hard-drawn tubing, the order should read:

> Tubing - copper, type "L," 1/2 inch O.D., hard-drawn, straight, in 20-ft lengths for refrigeration work.

With this information you can be sure of getting the correct size and type of tubing for use in refrigeration systems.

TUBE FABRICATION

The fabrication of copper tubing is one of the basic responsibilities of the refrigeration specialist. Unless the copper tubing is cut, bent, flared, and swaged correctly, connections will leak and the refrigeration system will fail.

Tube Cutting

To cut tubing, use either a hacksaw or a tube cutter. The tube cutter is preferred because a much smoother cut can be made with it.

TUBING CUTTER

The tubing that is generally used for refrigeration work can be cut with the tube cutter. Tubing may be cut to exact length by placing the cutter wheel on the measured mark (see figure 46) and turning the cutter slowly around the tubing. After each turn of the cutter, additional pressure (about 1/4 turn on handle) is applied to the cutter wheel until the tubing is cut. Excessive tightening of the cutting wheel will leave burrs on the inside of the tube, cause it to collapse, or become out-or-round.

A sharp tube cutter will leave little burring on the inside of the tubing; however, most cutters have a reamer as shown in figure 47. The reamer is used to smooth the inside of the cut. When the reamer is not in use, it should be turned around to prevent injury to the operator. The tubing should be held in such a position as to insure that no chips or filings fall inside the tube.

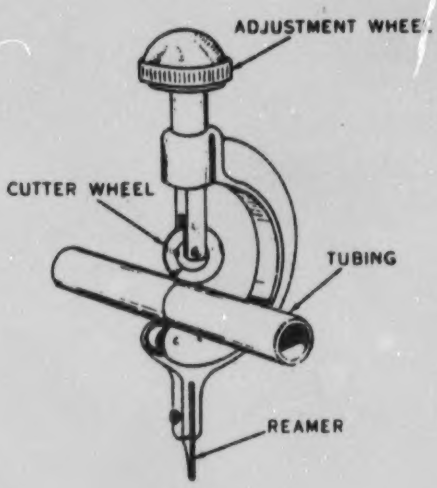


Figure 46. Using Tube Cutter

Figure 47. Using the Tubing Cutter Reamer

If a soft tubing is used, the ends of the portion not to be used should be crimped, capped or pinched to keep it clean and free from moisture for further use. If hard tubing is used, the ends should be capped or plugged.

Some tube cutters have a specially designed flare cut-off groove in the rollers. If a flare should become damaged and need to be removed, the flare is fitted into this groove and the blade cuts it off at its base with very little waste (see figure 48).

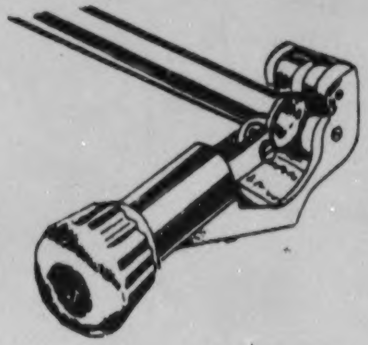


Figure 48. Using the Flare Cut-Off Groove

If a tube cutter is sprung out of shape, the wheel probably will not track around the tube. It may cut a thread instead of staying in the same groove. Therefore, it is important that you take care of your cutter.

If a hacksaw is to be used, a blade of 32 teeth per inch is preferable. Extra care must be taken to insure that the cut will be square. This can be accomplished with the use of a miter box as illustrated in figure 49. After the tube has been cut, its ends must be reamed or freed from burrs.

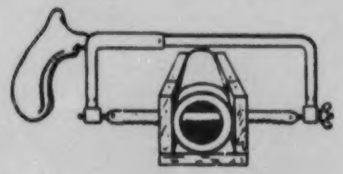


Figure 49. Cutting Tubing with a Hacksaw

Tube Flaring

The first and most important step in flaring is the preparation of the tube. The ends of the tube, both inside and outside, should be smooth and completely free of burrs. If this is not accomplished, it is almost impossible to produce a leak-proof connection.

A flaring kit consisting of a flare block and a yoke is used to produce flares (see figure 50). Special precaution should be taken to assure that these tools are always clean and in good condition.

To produce a flare of the correct size, the tube must be inserted into the flare block so that it extends above the surface of the block a distance equal to the depth of the bevel in the flare block (see figure 51). The yoke spinner should then be tightened down on the tubing end approximately three-fourths of a turn and back it off approximately one-fourth of a turn. Tighten it three-fourths of a turn and again back off one-fourth of a turn. In this way a flare of the correct size and contour is made with little or no danger of cracking the tube.

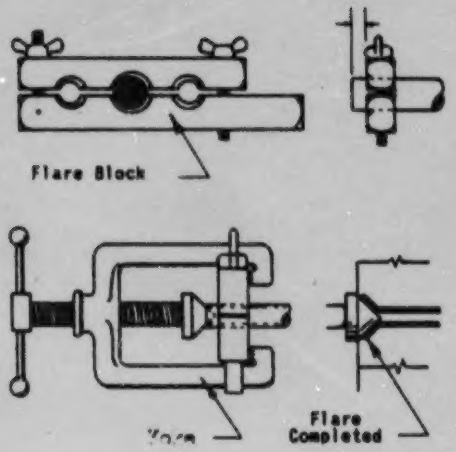


Figure 50. Using a Flaring Kit

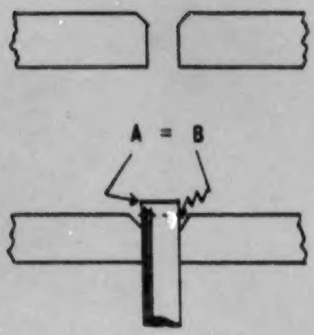


Figure 51. Recommended Allowance for Flaring

The flare is shaped to about seven-eights of its full contour so that when it is tightened into its fitting, the flare will assume the shape of the fitting. The spinner should never be tightened too much under any circumstances or the tube wall will be thinned and weakened.

A completed flare should fill 75 percent of the flare seat inside the flare nut. The completed flare should not be large enough to come in contact with the threads inside the flare nut as copper particles taken from the flare may prevent a leak-proof connection.

Care should be taken to insure that the flare nut is installed on the tube before it is flared because it cannot be installed after the flare has been made.

Tube Bending

Considerable time and attention must be devoted to practice in order to become competent in bending tubing. The smaller size tubing that will be used in domestic refrigerators can be bent easily by hand. However, a much neater and more satisfactory bend can be made with special tools. Care should be taken when bending tubing to maintain the roundness of the tube and not allow it to flatten or collapse. This may be accomplished by bending the tube into as large a radius as possible. The minimum radius that tubing may be bent is five times the diameter of the tube. However, if possible, the tube should be bent between five and ten times the diameter. The complete bend should not be made in one operation, but should be made slowly so as not to place too much strain in any one place. All types of tubing are easier to bend if they are annealed. However, hard tubing can also be bent if the proper tools are used. When bending soft tubing, precautions should be taken because the more it is worked, the harder it becomes. Therefore, you should determine where the bend is to be made before starting the bend. If for any reason you should need to straighten the tube after a bend has been made, it is necessary to anneal the tubing before attempting to straighten it.

Hand bending may be accomplished with the aid of a round block or a short section of a large pipe, but to form a bend with a high degree of accuracy, special bending tools must be used.

A tube bending spring may be used to bend tubing by hand when a high degree of accuracy is not required. These springs (see figure 52) come in all sizes and are made for both internal and external use. The internal spring is for use near the ends of the tubing or flared tubing, while the external is best used in the middle of long lengths of tubing. The purpose for using these springs is to prevent buckling of the tubing.

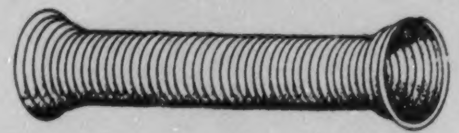


Figure 52. Tube Bending Spring

The bending spring has a tendency to bind on the tube. This can be eliminated by twisting the spring to cause the external spring to expand or cause the internal spring to contract. It may also be eliminated by bending the tube slightly farther than is desired, and then backing it up to the desired angle. This will loosen the spring, thus enabling it to be removed very easily.

Another type of tube bender which is known as the lever type (see figure 53) is used to make bends in tubing when a high degree of accuracy is required. Many times installations are made in close areas such as closets or under staircases or foundations, and bends must be made at specific angles in order for the tubing to connect the units. Not only does this tube bender provide an accurate means of fabricating bends, but it also helps to make a neat installation. Although the lever type bender is light in weight, it is also very strong and durable.

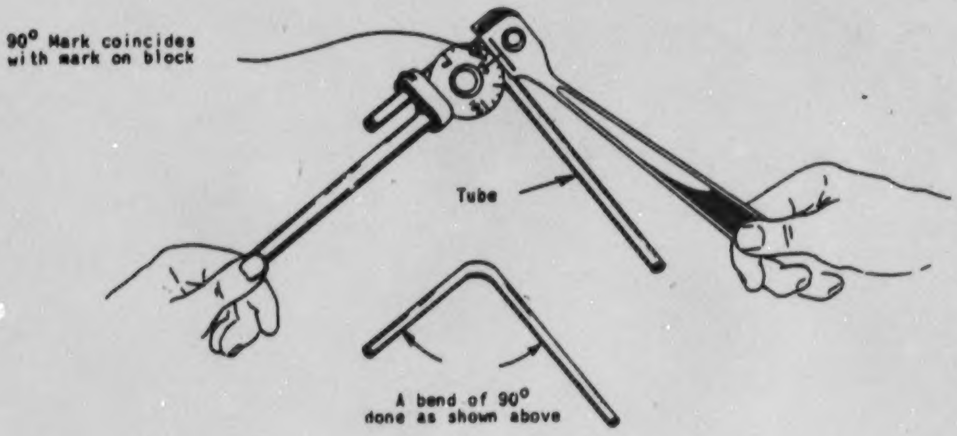

90° Mark coincides with mark on block
Tube
A bend of 90° done as shown above

Figure 53. Lever Tube Bender

Gear-type tube benders are especially valuable for bending hard drawn copper, stainless steel, and other types of hard tubing. They also offer advantages in that they are compact and easy to operate (figure 54).

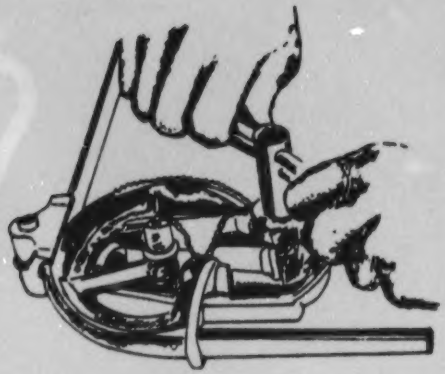


Figure 54. Gear-Type Bender

The gear ratio of this type tube bender makes it easier to bend all types and sizes of tubing. The gear-type bender is generally smaller than a lever type of comparable size.

FITTINGS

Fittings are used to join two or more refrigeration lines together or to connect one or more lines to a unit. While all fittings have the same purpose, they may differ in composition, type, size, thread, and shape.

Fittings used in a refrigeration system may be made of several kinds of metals, depending on the type of refrigerant used, pressure on the lines, and size of the units.

Types of Fittings

Common types of fittings used in refrigeration systems consist of sweat, flare, and pipe.

Refrigeration flare type fittings differ from aircraft and commercial fittings. This difference is in the cone angle; therefore, no attempt should be made to substitute other fittings of this type.

Figures 55, 56, 57, and 58 are illustrations of refrigeration fittings. Study these illustrations to become familiar with the fittings; you will be required to use this information many times in this course and in the field as a refrigerant specialist.

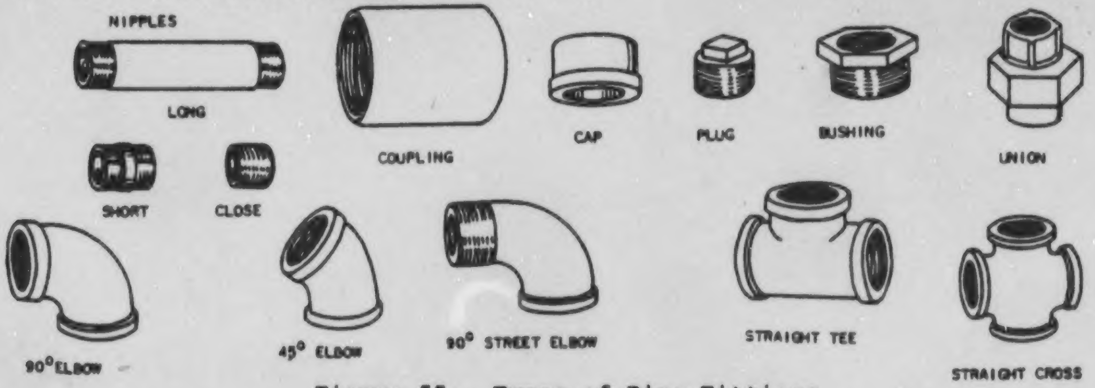
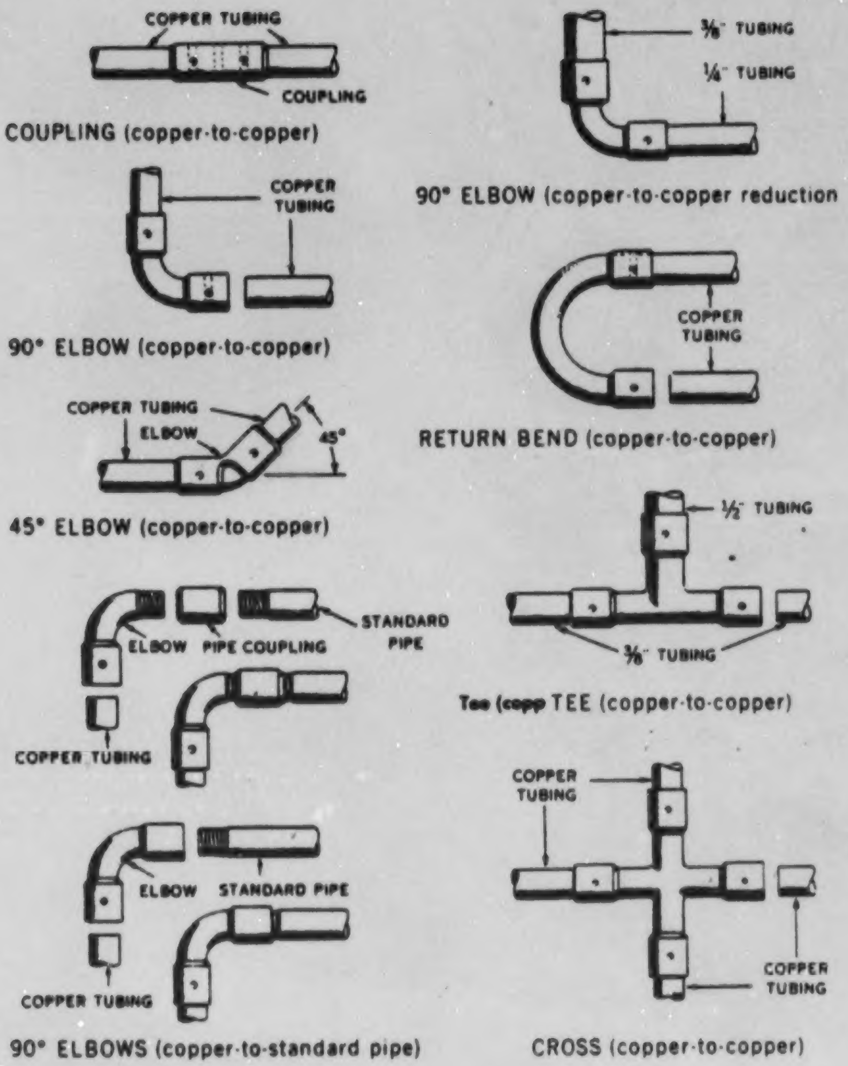


Figure 55. Types of Pipe Fittings


COPPER TUBING
COUPLING
⅜" TUBING
¼" TUBING
COPPER TUBING
COPPER TUBING
COPPER TUBING
ELBOW
45°
½" TUBING
ELBOW
PIPE COUPLING
STANDARD PIPE
⅜" TUBING
COPPER TUBING
COPPER TUBING
ELBOW
STANDARD PIPE
COPPER TUBING
COPPER TUBING

COUPLING (copper-to-copper)

90° ELBOW (copper-to-copper reduction

90° ELBOW (copper-to-copper)

RETURN BEND (copper-to-copper)

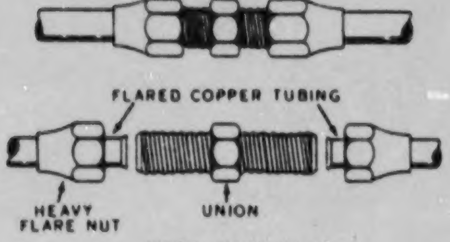
45° ELBOW (copper-to-copper)

Tee (copp TEE (copper-to-copper)

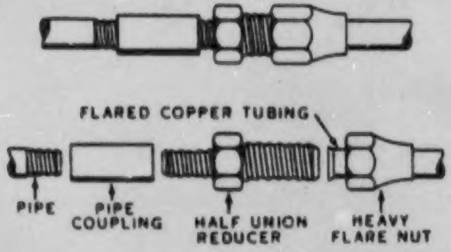
90° ELBOWS (copper-to-standard pipe)

CROSS (copper-to-copper)

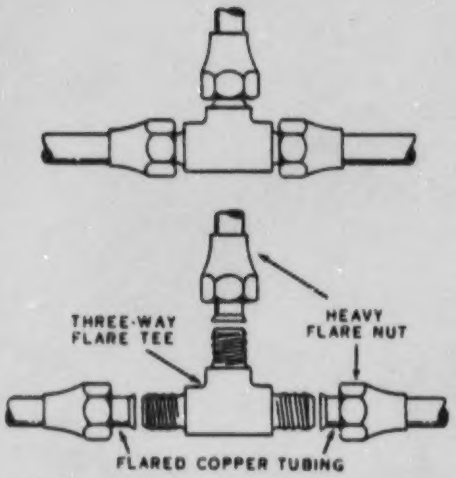
Figure 56. Sweat Fittings (Copper)


FLARED COPPER TUBING
HEAVY FLARE NUT
UNION

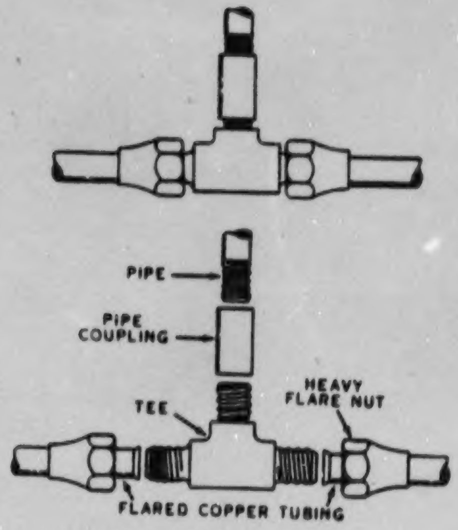
UNION - MF TO MF


FLARED COPPER TUBING
PIPE
PIPE COUPLING
HALF UNION REDUCER
HEAVY FLARE NUT

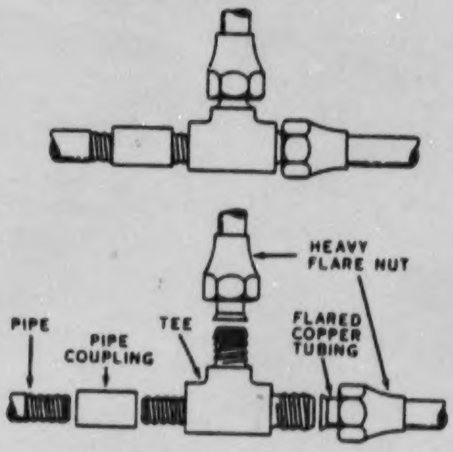
HALF UNION REDUCER - MF TO MPT


THREE-WAY FLARE TEE
HEAVY FLARE NUT
FLARED COPPER TUBING

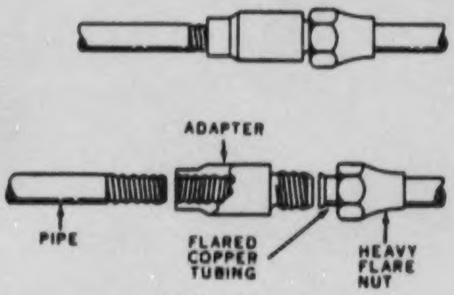
TEE - MF TO MF TO MF


PIPE
PIPE COUPLING
TEE
HEAVY FLARE NUT
FLARED COPPER TUBING

TEE REDUCER - MF TO MF TO MPT


HEAVY FLARE NUT
PIPE
PIPE COUPLING
TEE
FLARED COPPER TUBING

TEE - MF TO MPT TO MF


ADAPTER
PIPE
FLARED COPPER TUBING
HEAVY FLARE NUT

ADAPTER - MF TO FPT

Figure 57. Flare Fittings (Brass)

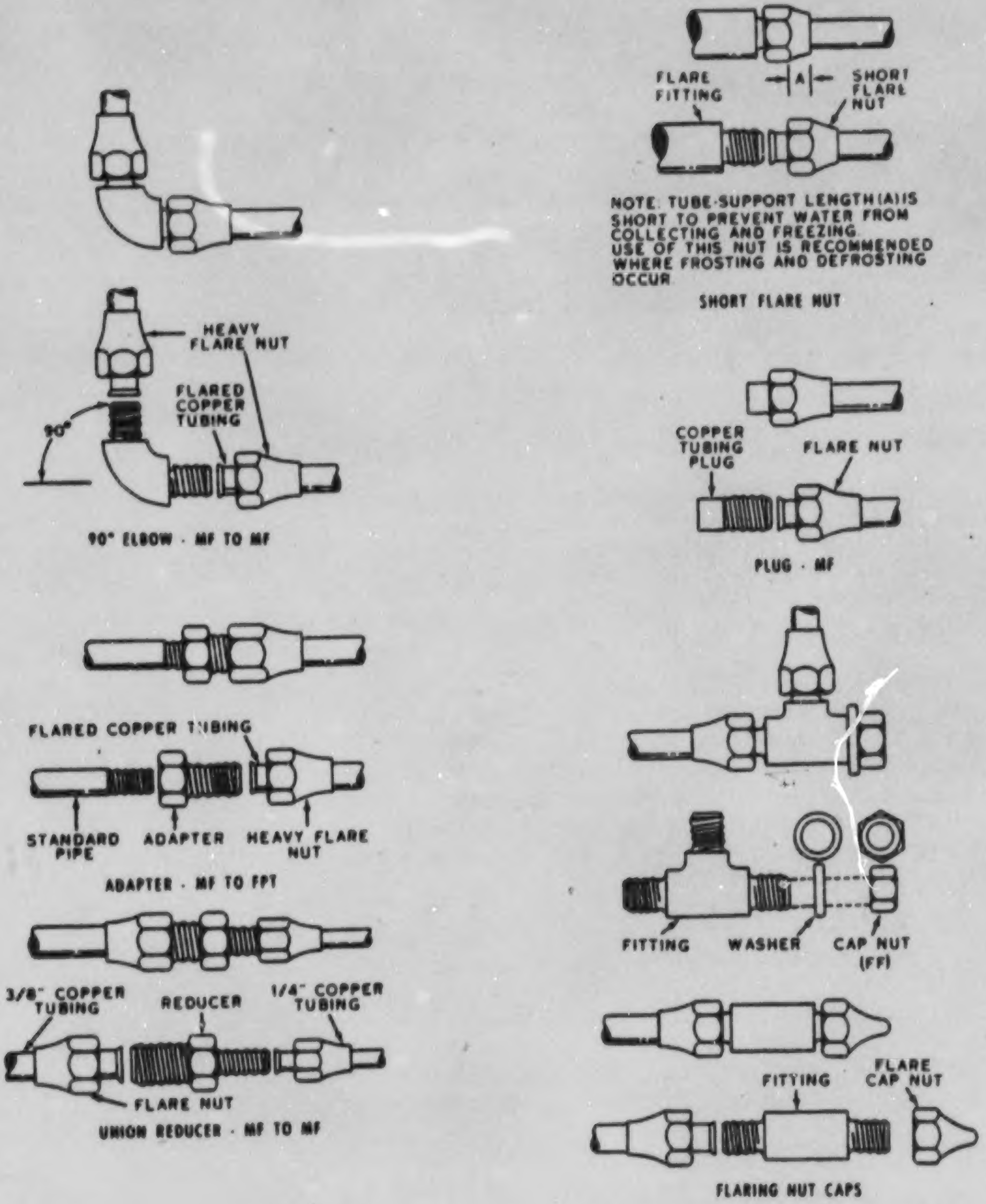

FLARE FITTING
A
SHORT FLARE NUT
NOTE: TUBE-SUPPORT LENGTH(A)IS SHORT TO PREVENT WATER FROM COLLECTING AND FREEZING. USE OF THIS NUT IS RECOMMENDED WHERE FROSTING AND DEFROSTING OCCUR.
SHORT FLARE NUT
HEAVY FLARE NUT
FLARED COPPER TUBING
90°
90° ELBOW - MF TO MF
COPPER TUBING PLUG
FLARE NUT
PLUG - MF
FLARED COPPER TUBING
STANDARD PIPE
ADAPTER
HEAVY FLARE NUT
ADAPTER - MF TO FPT
FITTING
WASHER
CAP NUT (FF)
3/8" COPPER TUBING
REDUCER
1/4" COPPER TUBING
FLARE NUT
UNION REDUCER - MF TO MF
FITTING
FLARE CAP NUT
FLARING NUT CAPS

Figure 58. Flare Fittings (Brass)

IRON PIPES

Iron pipe is used in the refrigeration industry in three major applications.

1. In secondary refrigeration systems, it is used to transfer water or brine from the chiller to the cooling coil.

2. In primary refrigeration systems, it is used to transfer the water from the condenser to the water tower and back.

3. In systems using ammonia as a refrigerant, it is necessary to use black iron pipe because ammonia corrodes copper.

Swaging

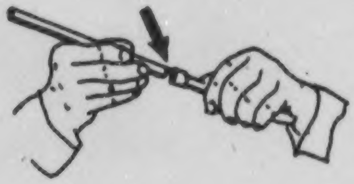


Figure 59. Swaging

Swaging is the process by which the end of the one piece of tubing is stretched or expanded in order that the end of another piece of tubing of the same size will fit into it. (See figure 59.) The joint will then be sealed by soldering or brazing. By swaging the use of a fitting is eliminated.

The most important factor in joining tubing is to have proper clearances between the parts. An easy slip fit with the tubing should approximate the range of .0015 to .005 inch. To insure proper centering of the male part, insert it so as to evenly contact the shoulder of the swaged member. This insures a uniform distribution of the alloy, with no voids and prevents the alloy from dripping into the inside of the tubing, where it could cause a restriction in the tubing or even equipment damage.

Swaging can be used in close places, where there is not room for fittings. A good swage connection will reduce the possibilities of leaks.

The swaging kit consists of a swaging punch and a swaging block as illustrated in figure 60. The swaging punch has a small portion (called a pilot) which fits easily into the inside of the tubing, and a tapered lead which connects this pilot with an enlarged portion which is slightly larger than the outside diameter of the tube.

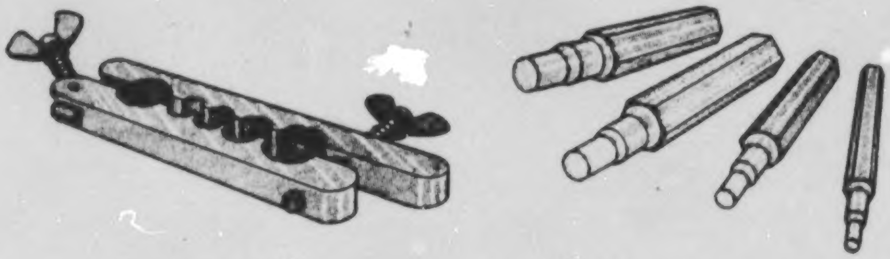


Figure 60. Swaging Kit

Swaging should be accomplished as follows:

1. Use backside of block (side opposite bevel).
2. Clamp tube into proper size hole in block.
3. Extend tube above block a distance equal to the distance from the bottom of the swaging punch to the top of the bevel, as illustrated in figure 61.
4. Hold block firmly in hand.
5. Using a hammer, drive the swaging punch into the tube (swaging punch should be turned slightly after each stroke.

The completed swage will have an inside diameter slightly larger than the original outside diameter of the tube and should always have a depth at least equal to the original outside diameter.

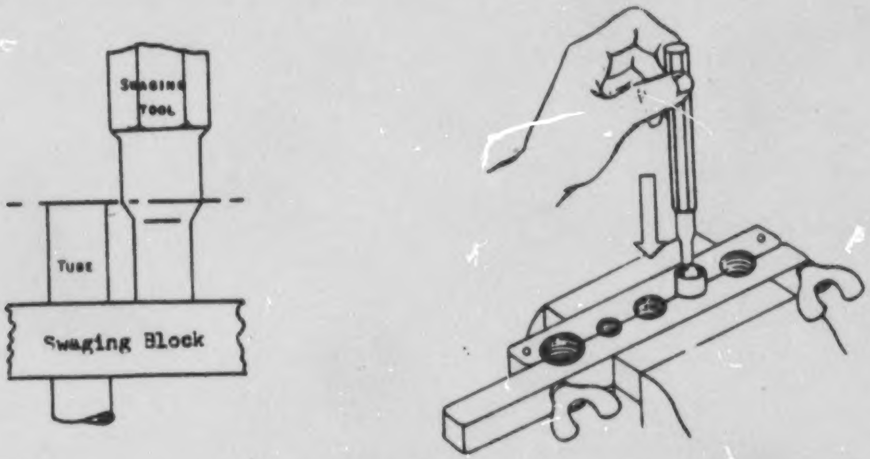


Figure 61. Swaging Block

A swage should not be made within one inch of the point where a flare or a bend is located. The swaged portion of the tubing will have a double thickness, making it very difficult to bend. In flaring, it may be impossible to slip the flare nut back far enough on the tube to properly clamp the tube into the flaring block.

If swaging is properly accomplished, it will make a connection stronger than the tubing itself.

All refrigeration specialists must have a very good understanding of tube fabrication. This must include such things as measuring, cutting, flaring, swaging, and bending.

QUESTIONS

1. Why should all copper lines contain one bend?
2. What are the five types of copper tubing?
3. What is the largest size of refrigeration service tubing obtainable?
4. What is the color code of refrigeration service tubing?
5. What are two common types of refrigeration fittings?
6. To make a flare, how much of the tubing should extend above the flaring block?
7. How is the term "annealing" defined?

REFERENCES

1. Imperial Tube Working Manual
2. Copper Tubing - Frank J. Versagi

SOLDERING

OBJECTIVE

To help you in learning:

- The terms used with the oxyacetylene and hydrocarbon torch
- Safety precautions
- Use of oxyacetylene torch and hydrocarbon torch
- Soft soldering, silver brazing, and aluminum brazing

INTRODUCTION

It is the refrigeration specialist's job to make silver brazed soft solder, and aluminum brazed joints and connections. This type of work, at times, requires the use of oxyacetylene equipment.

The equipment used for the oxyacetylene torch consists of a source of oxygen and acetylene, two regulators, two lengths of hose with fittings, and a torch tip. In addition, a friction lighter to light the torch, gloves to protect the hands and wrenches for the various connections on the cylinders, regulators, and torches.

HYDROCARBON TORCH

A portable hydrocarbon torch (see figure 62) is usually used for heating materials to be soldered. However, if a hydrocarbon torch is not available, other sources may be used.

The major component parts of the hydrocarbon torch are:

1. Torch handle
2. Stem (Tips)
3. Regulator
4. Fitted hose

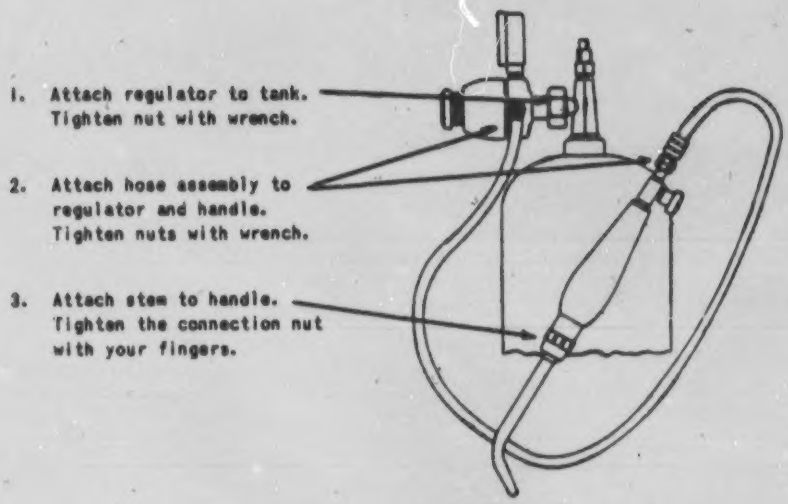

1. Attach regulator to tank. Tighten nut with wrench.
2. Attach hose assembly to regulator and handle. Tighten nuts with wrench.
3. Attach stem to handle. Tighten the connection nut with your fingers.

Figure 62. Hydrocarbon Torch

Methods of Soldering

There are two soldering methods: the direct flame method in which the flame heats the workpiece and the workpiece melts the solder, and the indirect flame method. In the indirect method, the flame heats the soldering iron. The iron in turn heats the workpiece, and the workpiece melts the solder.

A hydrocarbon torch or an oxyacetylene torch can be used for the direct flame method. For indirect soldering, a soldering iron similar to that in figure 63 can be used.

SOLDERING

It take considerable time and practice to become competent in soldering. Soldering is the process of applying a molten metal to hot metals that are not molten. The hot solder flows into the pores of the metals being joined and as it changes state from a liquid back to a solid, a strong joint is obtained.

To solder satisfactorily, the surfaces to be soldered must be very clean and must remain clean throughout the soldering process. Also, a sufficient quantity of heat must be used.

In soldering copper tubing, the outside surface of the tube and the inside surface of the fitting should be cleaned until the metal is bright. There should be no discoloration, grease, dirt, or oxides remaining on the surface to be soldered. The cleaning method, most generally used, is to clean the outside of the tube with steel wool and the inside of the fitting with sandpaper wrapped around a round object, such as a pencil.

Use of Flux

After cleaning, a thin uniform coating of noncorrosive soldering flux should be applied to the tube with a brush or paddle. Flux should not be applied with fingers or any oily object. If the flux is applied too thickly, the excess flux may form bubbles when heated and prevent the solder from flowing into the joint.

When using flux, the following must be observed: apply the flux evenly to the metal surface, if the flux wets the surface easily and smoothly this indicates the tube is clean and ready for joining. If the flux balls up and spreads unevenly, the surface is dirty and requires cleaning again.

In addition, the behavior of the flux when heated can be used as a temperature guide. For instance, one brand becomes white and puffy at about 600 degrees. At 800 degrees it smooths out and turns a milky color and at 1100 degrees it turns clear and the bright metal surface will show through the flux.

A noncorrosive flux is an antioxidizing agent and can only keep the metal clean once it has been cleaned mechanically. A corrosive flux must not be used in refrigeration work, as it corrodes the metal.

A very important step in good soldering is that the materials being joined must be hot enough to melt the solder. This is the only way that solder will flow into the pores of the metal. After applying the heat, touch the solder to the metal to be soldered. If the metal is clean, fluxed, and of the correct temperature, the solder will flow into the pores of the metals to be joined. If the solder is heated with the torch, a poor connection will result.

Soft Solder

Normally, any solder that melts at a temperature of less than 600° F is referred to as soft solder.

A 95-5 solder (95 percent tin and 5 percent antimony) is recommended for refrigeration work. This type of solder is referred to as a refrigeration solder.

Never use a solder that contains lead. The molecules of lead are so large that they will not flow into the pores of the copper to make a refrigerant-tight seal.

SILVER BRAZING

Silver brazing is the process of joining metals together by the use of a silver alloy with a melting temperature between 1000° to 1150° F. These alloys contain around 45% silver.

One of the essentials of a brazed joint is that there be contact between absolutely clean surfaces. The first act of cleaning may be done with a scraper, file, emery cloth, or steel wool. A metal that has been cleaned immediately oxidizes on exposure to air. The layer of oxide, no matter how thin, will not form an alloy with another metal; therefore, brazing cannot be performed between oxidized surfaces. However, a certain amount of oxidation cannot be avoided; for this reason, fluxes are used to help prevent oxides from forming. A good flux is necessary when silver brazing. The flux is needed to prevent oxides from forming on hot metals.

Phos copper is another type of silver alloy and may be used to join copper to copper without using flux. This type of alloy has the flux or cleaning agent built into the rod. It is an advantage to use no flux when the tubing or parts are joined in a system which should be kept clean.

Remember: A clean, dry refrigeration system is one that keeps working year after year without giving any trouble.

Types and Use of Different Alloys

If properly used, the alloys used to join metals together will become twice as strong as the metal itself. The alloys listed are all suitable for working with copper, the easy-flo 3, sil-fos, and phos copper are considered best for low temperature brazing. Sil-fos and phos copper are for use with non-ferrous metals only and do not require the use of a flux.

Easy-flo 3 is 50% silver alloy, with the addition of 3% nickel. The other easy-flo numbers give the percentage of silver in the alloy also. Alloys with a large spread between the melting point and the flow point are easier to work with, since the alloy with a large spread has a better chance of making a good tight joint before it cools and sets up hard. The following are different types of alloys and their working temperatures.

	MELTING POINT	FLOW POINT
Easy-flo - 50	1160 degrees	1175 degrees
Easy-flo - 45	1125 degrees	1145 degrees
Easy-flo - 35	1125 degrees	1295 degrees
Easy-flo - 3	1195 degrees	1270 degrees
Sil-fos	1185 degrees	1300 degrees
Phos-copper	1304 degrees	1382 degrees

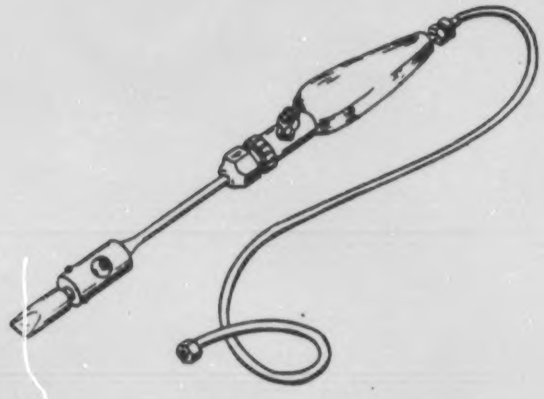


Figure 63. Hydrocarbon Soldering Iron

Electrical connections are normally soldered with a soldering iron. Tubing joints are soldered by the direct flame method. Figure 64 illustrates the steps to be followed when soldering tube joints. As with any activity, there are special precautions to be observed when soldering tubing joints, as illustrated in figure 65. Study figures 64 and 65 well; this is one job you will be required to do very often.

ALUMINUM BRAZING

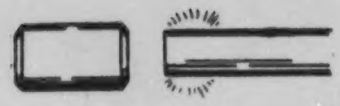
Aluminum brazing is the best method of repairing aluminum tubing such as found in aluminum evaporators. It is also more difficult to braze aluminum than other metals for several reasons.

First, the melting point of aluminum and the brazing rod are usually quite close. For example, pure aluminum has a melting point of 1218 degrees F. The aluminum brazing rod (Eutec #190) melts at 1070 degrees F. A difference of only 148 degrees. Therefore, extreme care must be taken when applying heat.

Second, there is no color change to aluminum as it is heated and once the melting point is reached,the aluminum tubing begins to crumble.

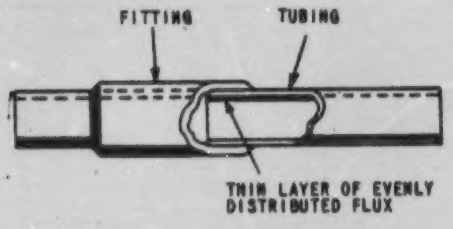
The brazing rod and the flux used must be designed for the particular aluminum alloy being joined or repaired. Aluminum brazing rods are color coded on one end according to their type, and the manufacturer lists the proper flux for each type of rod.

It is recommended that the purchase of aluminum brazing rods and the flux be from the same manufacturer due to the requirement for close compatibility between the rod and flux.


CLEAN, ROUND TUBING

1

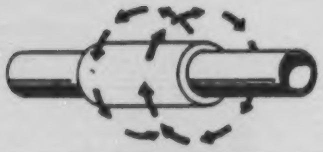
Clean the outside surface of the tubing and the inside surface of the fitting with steel wool until surfaces are bright and shiny. Test the end of tubing in the fitting to make certain it is free to extend full depth into the fitting surface.


FITTING
TUBING
THIN LAYER OF EVENLY DISTRIBUTED FLUX

2

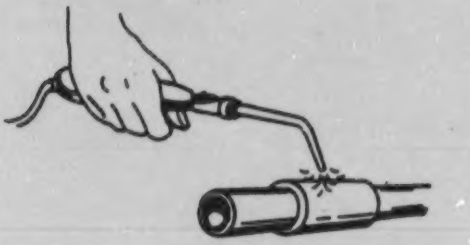
Apply a thin layer of suitable flux to the entire outside contact surface of the tubing and inside of the fitting.

NOTE: If too much flux is used, some will fall inside the tubing and clog the strainers, filters, and valves.


ROTATE TO DISTRIBUTE FLUX EVENLY

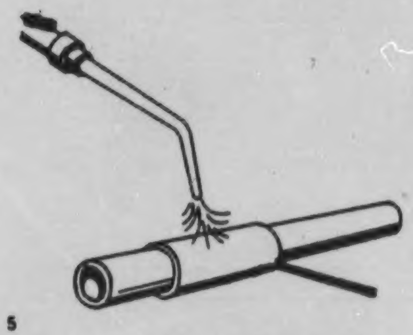
3

Insert the tubing in the fitting to its proper position and rotate back and forth to distribute flux evenly.



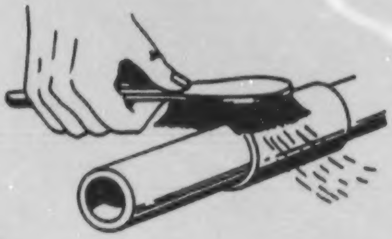
4

Apply heat to the joint until it reaches the melting temperature of the solder.



5

Feed solder through the edge of the fitting. When a continuous ring of solder appears at the end of fitting, the joint is complete.



6

Clean joints with wire brush, scraper, or emery cloth.

Figure 64. Soldering Copper Tubing

OXYACETYLENE COMBUSTION

The flame of a hydrocarbon torch will not heat the base metal hot enough for some soldering jobs. Therefore, when silver soldering, it is usually best to use an oxyacetylene flame. The oxyacetylene flame is derived from burning pure acetylene in the presence of oxygen. By using oxygen and acetylene, it is possible to obtain a flame hot enough to melt all commercial metals.

Oxygen

Oxygen is a very common element and one we come in contact with daily. For example, water is about 88 percent oxygen, the air we breathe is approximately 21 percent oxygen, and the earth is composed largely of oxides which are compounds of oxygen. Most of oxygen that is used commercially is obtained from the air. This is accomplished by freezing the air at -317°F which separates the oxygen from the nitrogen and other gases.

Although oxygen will not burn, it supports combustion very actively, more so than air. This characteristic of oxygen makes it desirable to use with acetylene for brazing and soldering.

Acetylene

Acetylene is the fuel gas of the oxyacetylene flame. It is produced by dissolving calcium carbide in water. Calcium carbide is made by fusing limestone and coke in an electric furnace.

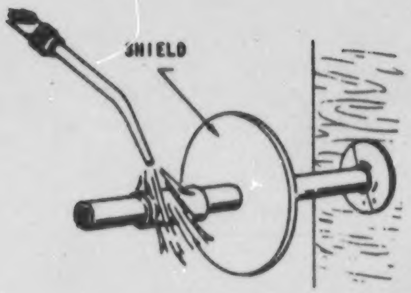
Acetylene is not an ordinary gas. It has characteristics peculiar in itself.

It contains about 93 percent carbon and about 7 percent hydrogen. When burned in the presence of pure oxygen, it burns at a temperature of 6000°F. Acetylene not only develops a large amount of heat, but also releases the heat units so rapidly that the highest temperature of the flame is produced almost instantly. At pressures greater than 15 psi, acetylene is unstable and may split up or disassociate. When pressure causes the gas to split up or decompose, this disturbance of the molecules releases heat until an explosion of the gas is produced.

It requires two and one-half (2-1/2) parts of oxygen to consume completely one (1) part of acetylene. It is not necessary, however, to supply all this oxygen through the torch, because a portion of the oxygen is derived from the air surrounding the flame. The torch is designed to supply one (1) part of oxygen to every part of acetylene that passes through it.

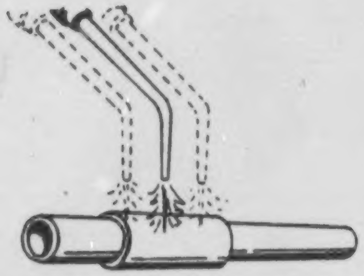
Types of Flames

The oxyacetylene torch will produce three different types of flames. The refrigeration specialist should be able to identify each of these flames and be able to adjust the regulators and torch to produce the type of flame required for each application.



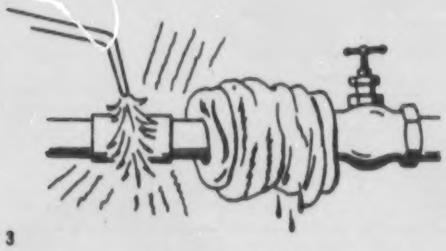
1

Use asbestos shield to protect walls and equipment.



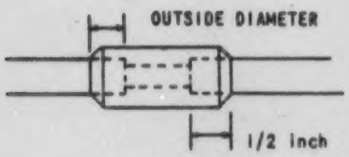
2

Move torch to distribute heat evenly on fitting. This prevents overheating of small area of fitting.



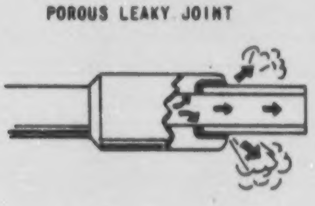
3

Protect valves and other fittings from extreme temperatures. Wrap a cloth saturated in cold water around section of tubing between joint and valve. This prevents heat traveling to valve.



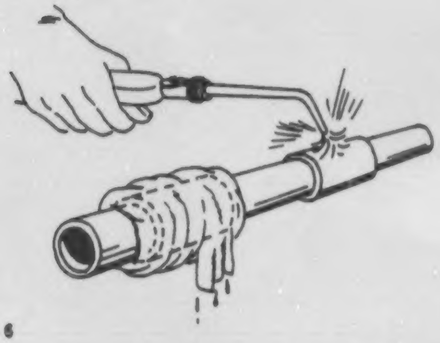
4

Check joints for proper depth. Tubing joints up to 7/16 of an inch in diameter should have depth equal to outside diameter of tube. Tubing joints greater than 7/16 of an inch in diameter should have depth of 1/2 inch.



5

Do not use silver solder over soft solder. It makes a porous, leaky joint.



6

Protect nearby soft-soldered joints when making silver-soldered joints. Rag or waste saturated with cold water prevents heat traveling to next joint.

Figure 65. Precaution for Soldering Copper Tubing

NEUTRAL FLAME. When the oxygen and acetylene are equally mixed, a neutral flame results (see figure 66). A neutral flame is usually used for welding and cutting.

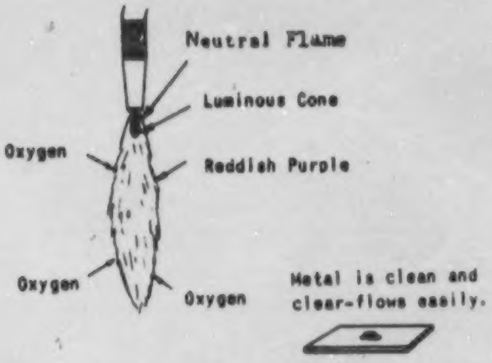

Neutral Flame
Luminous Cone
Oxygen
Reddish Purple
Oxygen
Oxygen
Metal is clean and
clear-flows easily.

Figure 66. Neutral Flame

CARBURIZING FLAME. The carburizing or excess acetylene flame (figure 67) contains excess carbon. This flame is usually used for heating metal for soldering and brazing.

OXIDIZING FLAME. The oxidizing flame (figure 68) results from an excess of oxygen. We never use the oxidizing flame in refrigeration. It is sometimes used by welders to melt rivets.

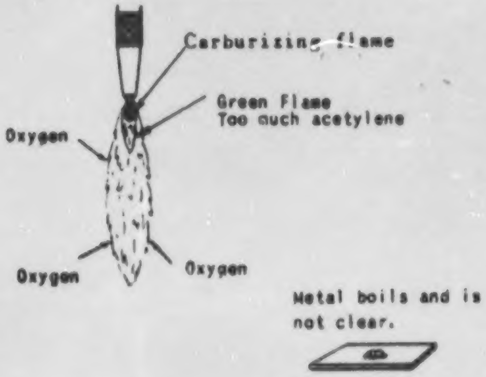

Carburizing flame
Green Flame
Too much acetylene
Oxygen
Oxygen
Oxygen
Metal boils and is
not clear.

Figure 67. Carburizing Flame

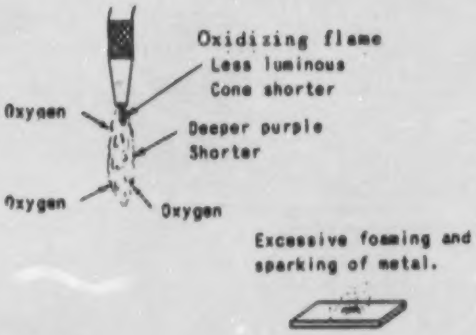
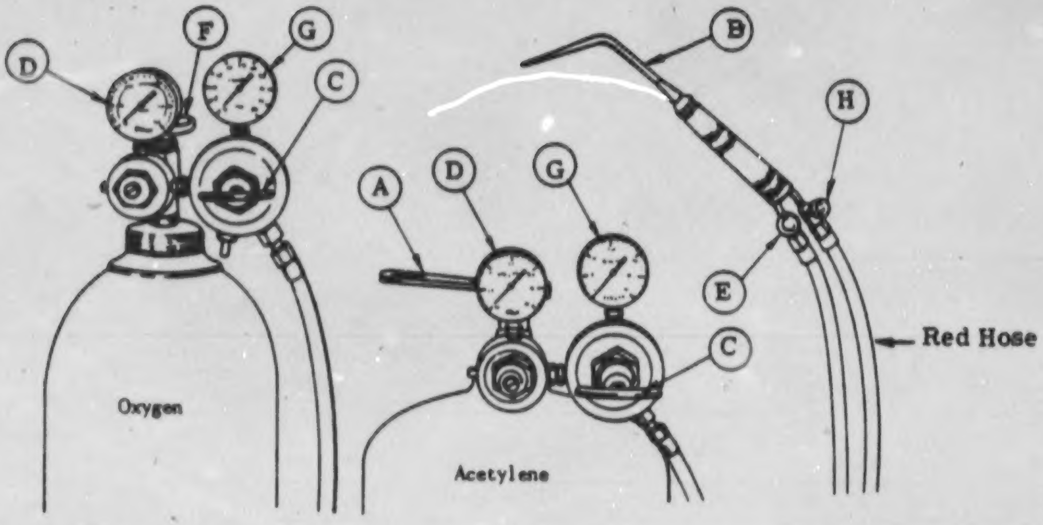

Oxidizing flame
Less luminous
Cone shorter
Oxygen
Deeper purple
Shorter
Oxygen
Oxygen
Excessive foaming and
sparking of metal.

Figure 68. Oxidizing Flame

OXYACETYLENE EQUIPMENT

The major items of the oxyacetylene equipment used in soldering are oxygen and acetylene cylinders, oxygen and acetylene regulators, gages, hoses, and torches (see figure 69). Knowledge of all these items will aid you in becoming not only a good mechanic but a safe one as well.



a. Acetylene Cylinder Valve Wrench
b. Torch Tip
c. Regulator Adjusting Screw
d. Cylinder Pressure Gages
e. Oxygen Needle Valve
f. Oxygen Cylinder Hand Valve
g. Regulator Outlet Pressure Gage
h. Acetylene Needle Valve

Figure 69. Identifying Acetylene Equipment

Oxygen Cylinders

Oxygen is stored in cylinders of seamless steel made to withstand high pressure. The initial charging pressure of these cylinders at the plant is 2200 pounds per square inch at 70° F. Oxygen, like other gases, expands as it becomes heated. Oxygen cylinders have a bursting disc on the cylinder valve that will burst, should the pressure in the cylinder become too high.

Acetylene Cylinders

There are several types of acetylene cylinders on the market. All are made in accordance with specifications set up by the Interstate Commerce Commission. The acetylene cylinder is filled with porous material which absorbs acetone. Acetone in turn has the property of absorbing many times its own volume of acetylene gas, thus the actylene is not in a free state and is known as dissolved acetylene. Under such conditions, acetylene can safely be compressed to a pressure of 250 p.s.i. at 70° F. Acetylene cylinders have fusible plugs which melt when pressure and temperature become too high.

Oxygen and Acetylene Regulators

The primary purpose of the regulators is to reduce the high pressure of the gases in the cylinders to the desired working pressure at the torch. Regulators also perform the function of maintaining a constant pressure in order that the flame may be perfectly steady and uniform.

Most regulators are either of the single-stage type or the two-stage type. Single-stage regulators reduce the pressure in one step or stage, while the two-stage regulators perform this same work in two steps or stages. Less adjustment is generally necessary when the cylinders are being used with two-stage regulators.

Regulators should always be turned off before turning on high-pressure gases to protect the regulator valve seats.

Gages are parts of the regulator assembly. There is one high-pressure and one low-pressure gage for each assembly (see figure 69). The high-pressure gage shows the pressure of the oxygen or acetylene in the cylinder. The low-pressure gage indicates the working pressure at the torch.

Hoses

The hoses that connect the regulator to the torch are built to withstand high internal pressure. The red hose has left-hand threads and is connected to the acetylene regulator. The green hose or black hose has right-hand threads and is connected to the oxygen regulator.

Torches

The torch is the unit used to mix the oxygen and acetylene in the correct proportions and to help control the volume of these gases burned at the tip. The torch handles are designed with two needles valves, one for adjusting the flow of acetylene and the other for adjusting the flow of oxygen.

There are two general types of torches, the low pressure or injector type and the medium or balanced pressure type. In the low pressure type, the acetylene may be used at less than 1 psi.

In an injector type torch, a jet of high pressure oxygen is necessary to produce a suction effect which draws in the required amount of acetylene. This is illustrated in figure 70. In the medium pressure torch illustrated in figure 71 the acetylene is operated at from 1 to 15 psi. These torches are designed to operate at equal pressures of acetylene and oxygen. You will use this type of torch in this course.

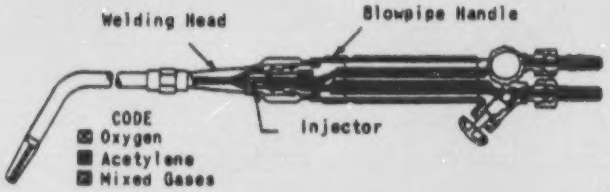


Figure 70. Low Pressure or Injector Type Torch

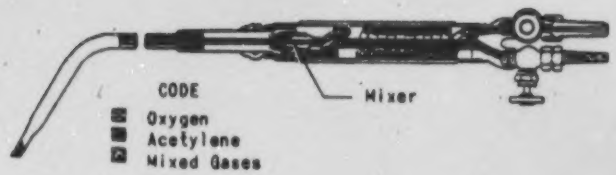


Figure 71. Medium or Balanced Type Torch

Torch tips

Various brazing and soldering jobs require differences in the total amount and concentration of heat. To obtain this difference, most torches have several tips of various sizes that can be exchanged conveniently and quickly.

The torch tip sizes are designed by numbers and each manufacturer has his own arrangement for classifying them. The manufacturer's charts should be used when selecting tips for different thickness of metal to be soldered or brazed.

Proper tip sizes and working pressures for the balanced-pressure type torch

Tip Size	Acetylene Pressure	Oxygen Pressure
00	1 psi	1 psi
0	1 psi	1 psi
1	1 psi	1 psi
2	2 psi	2 psi
3	3 psi	3 psi
4	4 psi	4 psi
5	5 psi	5 psi
6	6 psi	6 psi

Torch tips are made of copper or copper alloy and are made so that they seat well when tightened hand-tight. Torch tips should not be rubbed across abrasive firebrick or used as tongs to position work. When torch tips become clogged, they must be cleaned with torch tip cleaners. Care should be exercised in cleaning tips so that the orifices are not enlarged. A partially clogged tip can cause popping of the torch.

> CAUTION: Failure to tighten the tip in the handle or a scratched seat can result in a flashback (burning of acetylene where tip screws into handle).

Inspection and Maintenance

Oxtyacetylene equipment has been designed to operate without lubricants. Visual inspections for wear, leaks, and malfunctions should be made each time the equipment is used. It is most important that equipment be kept clean at all times. The presence of grease or oil with oxygen under pressure will cause spontaneous combustion. If troubles do appear in oxyacetylene equipment, consult TO 34W4-1-5 for corrective measures to be taken.

SAFETY PRECAUTIONS WHEN USING OXYACETYLENE EQUIPMENT

An important thing for one to remember when performing an activity is to work SAFELY. The oxyacetylene equipment is not hazardous, but it must be remembered that the mechanic is working with gases of high pressure and the hottest flame known to man. In view of this, certain precautions are necessary for safety. The following are precautions that a mechanic should know so well that they become automatic in his actions.

1. NEVER use oil on oxyacetylene equipment. Oxygen under pressure is likely to cause an explosion if it comes in contact with oil or grease. If the threads of a connection will not work smoothly, merely rub the lead of a pencil on the threads. Sufficient graphite will be deposited to provide lubrication.

2. Wear suitable clothing. Clothing should be free of oil and grease. If clothing is of the type that will burn readily, use a leather apron.

3. Call oxygen by its proper name. Do not refer to oxygen as air, for if used in place of compressed air on oil or grease, you may cause an explosion.

4. Do not refer to acetylene as gas. Refer to it as acetylene.

5. Do not release oxygen or acetylene in confined spaces. This sets up not only a fire hazard but an explosive hazard.

6. Wear proper goggles. Adequate eye protection should be afforded at all times.

7. Do not use acetylene at pressure greater than 15 p. s. i. Acetylene gas, dissolved in acetone and contained in an acetylene cylinder, tends to disintegrate and an explosion may result.

8. Use a friction lighter to light the torch. Although the torch can be lit with a match, serious burns can result.

9. Do not use cylinders for supports or forming dies.

10. Never lay the torch down and walk off, leaving it burning.

11. Do not burn the place down. Torch in careless hands can be dangerous. Do not burn your hose or your buddy. Be careful and use common sense with a lighted torch.

12. Do not work on containers that have been used to hold gas or combustible materials. If it is necessary to braze a container that has contained combustible materials, steam-clean it thoroughly and drift dry nitrogen through it during the brazing process.

13. Do not store oxygen with acetylene, propane, gasoline, or other fuels.

14. Never transfer acetylene from one cylinder to another.

15. If you should start a fire, shut off your acetylene cylinder before doing anything else.

16. Should a flashback occur, shut off the acetylene cylinder and if necessary, increase the oxygen to the tip.

SUMMARY

The ease of handling and high heat conductivity makes copper tubing highly desirable for use in refrigerations systems. Copper tubing is divided into five different types; however, the refrigeration specialist usually uses only one type and that is refrigeration service.

There are two main types of fittings used in refrigeration work. These are the flare and sweat types. The flare type is used where there may be a reason for opening the line at some future date. The sweat type fitting is usually cheaper and easier to install so they should be used wherever possible.

QUESTIONS

1. What temperature ranges are required for the following?
    a. Soft solder
    b. Silver solder
2. How many parts of oxygen are required to consume one part of acetylene?
3. What are the three types of oxyacetylene flames and how can they be recognized?
4. What temperature is attainable with acetylene flame?
5. Oxygen is stored in cylinders at what pressure?
6. Acetylene is stored in cylinders at what pressure?
7. What are regulators used for?
8. What is the maximum working pressure for acetylene?

REFERENCES

1. TO 34W-4-1-5, Welding - Theory and Application
2. Prest-o-lite Bulletins 9514-3, F-9061-G, and 92095-D

WORKBOOKS 3ABR54530-I-1-P1 thru I-5-P7

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

FUNDAMENTALS

April 1975

SHEPPARD AIR FORCE BASE

11-6

Designed For ATC Course Use

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LOCATING SPECIFIC INFORMATION IN AFR 127-101,

OBJECTIVE

To be able to use AF Safety Publications and find selected information.

INSTRUCTIONS TO STUDENT

Listed below are six (6) incomplete statements taken from AFR 127-101, Industrial Safety Accident Prevention Handbook. Using the alphabetical index in the back of AFR 127-101, locate and record the missing information and specific paragraph number in which you found this information.

1. Accidents do not happen without ______________________________.

2. The largest percent of all Air Force ground accident fatalities can be attributed to

____

______________________________.

3. Personnel working with or near machinery will not wear loose clothing, __________

or ______________ that may become tangled in revolving parts of machinery.

4. When using the abrasive grinding wheel, the tool rest will not be more than

______________ inch from the grinding wheel.

5. Recommended weights which are considered within the safe limits for male and female workers required to perform continuous or repetitive lifting in compact

forms are ______________ pounds for male workers, and ____________ pounds for female workers.

6. Most drill press injuries are caused by drills ______________________ or flying out of the spindle.

Have the instructor check your work.

Checked by ______________________
Instructor

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Workbook 3ABR54530-I

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~~I-2-P1~~	~~Locating Specific Information in AFR 127-101~~	~~April 1975~~	~~3~~
I-3-P1	Identification and Selection of Hand Tools, Special Tools, Portable and Installed Shop Equipment	April 1975	4
I-4-P1	Identifying Copper Tubing	April 1975	7
I-4-P2	Cutting and Bending Tubing	April 1975	9
I-4-P3	Identifying Refrigeration Fittings	April 1975	11
I-4-P4	Flaring and Swaging Copper Tubing	April 1975	15
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I-5-P2	Hard Soldering	April 1975	20
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This supersedes WBs 3ABR54530-I-1 thru 5, September 1973
Copies of superseded publication may be used until the supply is exhausted.

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Tool No	Name	Size	Application
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			

What is the purpose of the 15° angle on the box end wrench? ____________________

____

____

Portable and Installed Shop Equipment

1. Identify the parts of the drill stand assembly by writing in each circle the letter opposite the name or the unit (figure 1).

2. What is the purpose of the key-type geared chuck? ____________________

____

____

____

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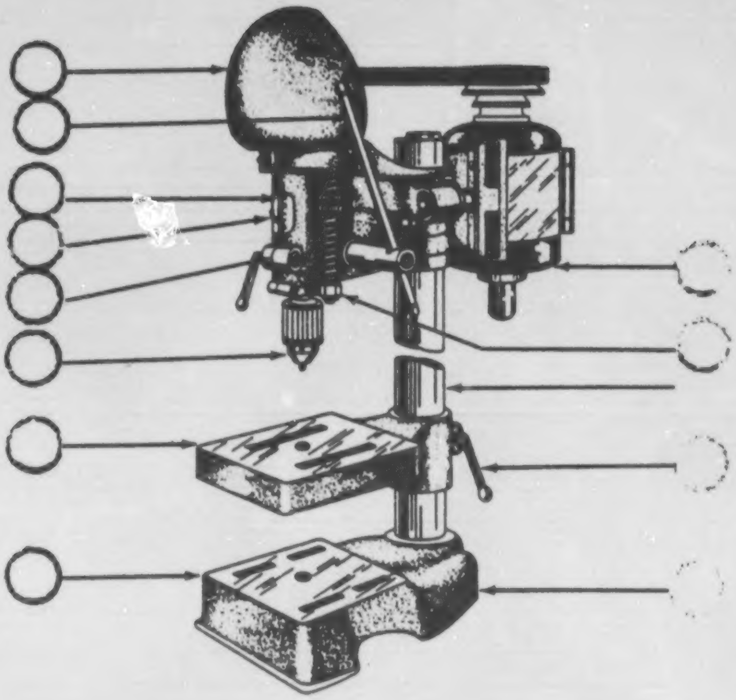

A.	Guard	G.	Feed lever
B.	Quill	H.	Motor
C.	Lower table	I.	Base
D.	Table	J.	Table clamp
E.	Chuck	K.	Column
F.	Pointer	L.	Depth stop

M. Quill lock

Figure 1

3. Why should the pressure be eased just before drilling through a piece of metal?

____

____

4. List two safety precautions to follow when using the drill stand.

a. ____________________________________

b. ____________________________________

Checked by ________________
Instructor

IDENTIFYING COPPER TUBING

OBJECTIVE

When you have completed this project, you will be able to identify the different types of copper tubing, as to sizes, application and color codes.

1. The tubing samples on the bench are numbered. Identify each sample by writing the type, size, and color code opposite the number that corresponds to the tubing sample. Under application list when, or where the tubing should be used.

Sample No	Type	Color Code	Size	Application
1				
2				
3				
4				

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Sample No	Type	Color Code	Size	Application
5				

2. Refrigeration tubing is sized by ______________________________

Checked by ______________________
Instructor

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CUTTING AND BENDING TUBING

OBJECTIVE

After completing this project, you should be able to cut and bend copper tubing.

CUTTING

1. Select a roll of 3/8-inch copper tubing.

2. Unroll approximately 2 feet of the tubing.

3. Measure and mark the tubing 8 inches from the end.

4. Install the tubing cutter so that the cutter wheel is over the mark.

5. If a tube cutter is not available, what may be used to cut the tubing?

   ____

6. Tighten the cutter wheel slightly (1/4 turn) against the tubing and revolve the cutter slowly around the tubing.

7. Continue revolving cutter, tightening slightly (approximately 1/4 turn) after each turn until the tube is cut through.

   CAUTION: Be careful not to drop the cutter and tube when the cut is completed.

8. Remove the cutter and insert reamer in the end of the tubing. Revolve the reamer until the burr is removed from the inside of the tubing.

9. Inspect the tube. If it is still rough on the end, smooth it very lightly with reamer.

   NOTE: The reaming procedures should be done with the open end of the tube pointing down so the filings will not fall into the tube.

BENDING TUBING 180°

1. Measure the exact center of the piece you have cut off and mark. It should be 4 inches. This is known as the "Center Mark."

2. To make a 180° bend and have the legs of the bend the same length, measure back to the left of the Center Mark 15/16 of an inch and mark. This is known as the "Start Mark."

3. Select the correct tube bender for 3/8-inch tubing.

4. Find the radius of the mandrel (that part of the bender which the tubing is bent around). Locate the "R" Index mark on the top handle of tube bender and the "O" Index mark on the mandrel.

5. Insert tubing into bender, making sure long part of tubing extends to your right. Place tubing lock on tubing.

6. Aline "R" Index mark on tube bender handle, Start Mark on tubing, and "O" Index mark on mandrel.

7. Bring handle down until "R" Index mark and 180° Index marks are alined.

8. Remove tubing from bender.

9. Check the bend for accuracy.

10. Have the Instructor check your work.

11. To make a 90° bend, follow above procedures, except step 3. Measure back 1/4 inch from Center Mark and mark your Start Mark. When making 90° bend, bring handle down until "R" and 90° Index marks are alined.

Checked by ______________________________
Instructor

IDENTIFYING REFRIGERATION FITTINGS

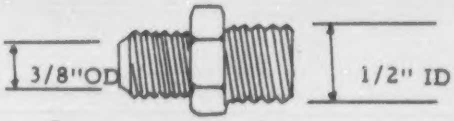
OBJECTIVE: When you have completed this project, you should be able to identify refrigeration fittings by type, size, and material; know how to determine the size of refrigeration fittings; and be able to match commonly used refrigeration fittings.

IDENTIFYING REFRIGERATION FITTINGS

1. Identify the following illustrated fittings by writing in the correct nomenclature in the spaces provided.

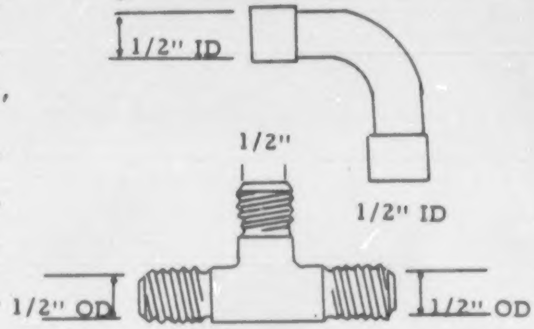
Example:

a. Fitting, refrigeration, brass, Half-union Reducer, 3/8" Flare to 1/2" MPT



b. Fitting, refrigeration, copper, ____________

____

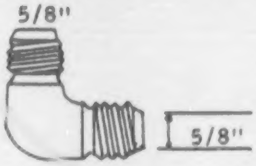


c. Fitting, refrigeration, brass, ____________

____

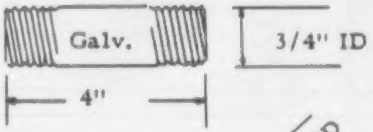
d. Fitting, refrigeration, brass, ____________

____



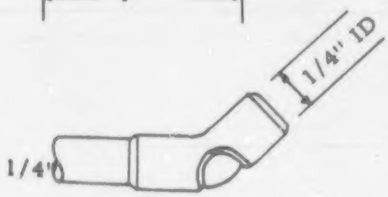
e. Fitting, pipe, ____________

____



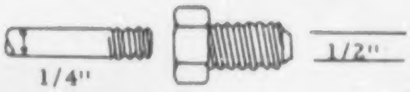
f. Fitting, refrigeration, copper, ____________

____



g. Fitting, refrigeration, brass, ____________

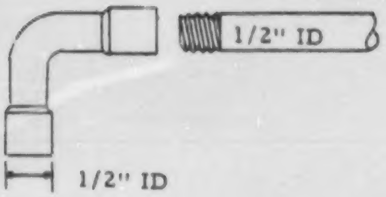
____



h. Fitting, refrigeration, brass,

____

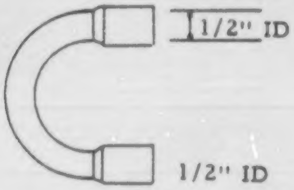
____



i. Fitting, refrigeration, copper,

____

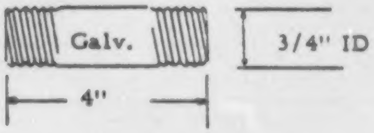
____



j. Fitting, pipe,

____

____



2. Identify each of the numbered fittings on the fitting ring, (furnished by instructor) and record the applicable information in the following blanks.

Number	Nomenclature	Material
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

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Number	Nomenclature	Material
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		

77.

3. Name the three main types of refrigeration fittings.

   a. ______________________

   b. ______________________

   c. ______________________

4. Name the two types of flare nuts.

   a. ______________________

   b. ______________________

5. How are sweat fittings measured? ______________________

____

____

Checked by ______________________
Instructor

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6. Tighten T-handle 3/4 turn moving the flaring face into the end of the tubing then loosen, continue this procedure until the flare is completed.

7. Remove the flaring yoke.

8. Loosen the wingnuts and remove the tubing.

9. Have the Instructor check your work.

10. To fabricate a flare on the opposite end of the 90° bend, follow the above procedures.

Checked by ______________________
Instructor

Swaging Copper Tubing

1. Ream both ends of the 180° copper bend.

2. Insert one piece of the copper tubing in the swaging block as illustrated in figure 4.

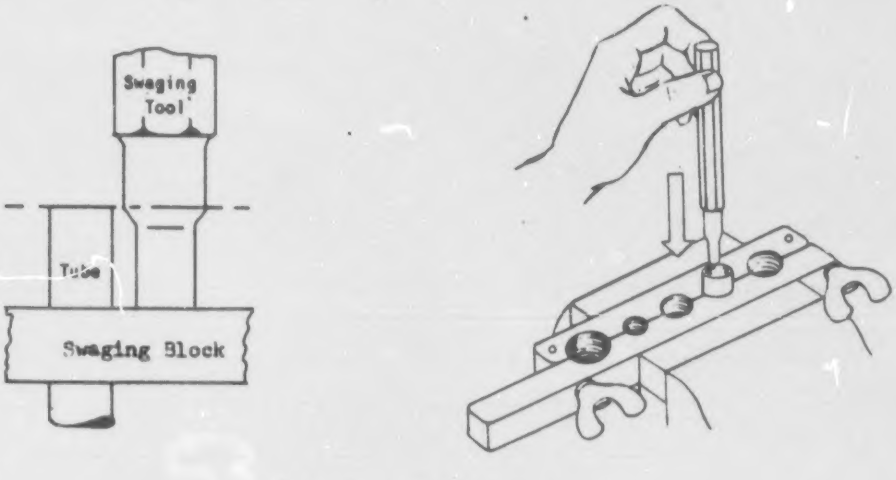

Figure 4. Swaging Block

FLARING AND SWAGING COPPER TUBING

OBJECTIVE

This project will aid you in gaining practical experience in flaring and swaging of copper tubing.

Flaring

1. Remove the burrs from one end of the 90° bend.
2. Place a 3/8-inch flare nut on the tubing.
3. Place the tubing in the flaring block (see figure 2).

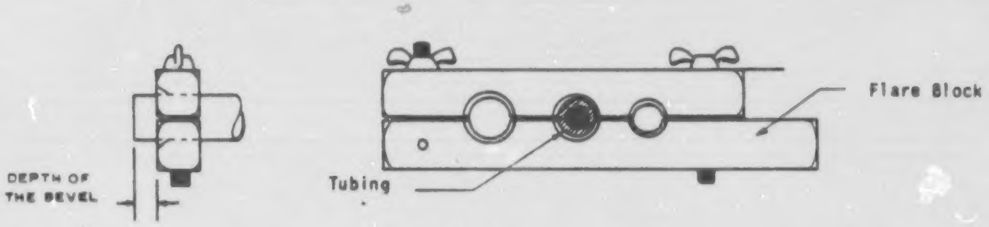

Figure 2. Tube Installed in Flare Block

NOTE: The tubing should extend above the flaring block a distance equal to the depth of the bevel.

4. Tighten the wingnuts on the flare block as tight as possible with your fingers.
5. Insert the flaring yoke over the flare block (see figure 3).

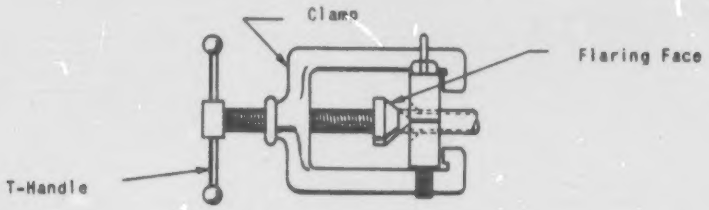

Figure 3. Flaring Yoke

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3. Insert the proper size swaging tool in the tubing as illustrated in figure 5.

4. Use light strokes with a ball-peen hammer and drive the swaging tool into the tubing.

   NOTE: The swaging tool should be turned slightly after each stroke.

5. Remove the swaging tool.

6. Remove the tubing from the swaging block.

7. Have the instructor check your work.

8. To fabricate a swage on the opposite end of the 180° bend, repeat steps 2 through 7.

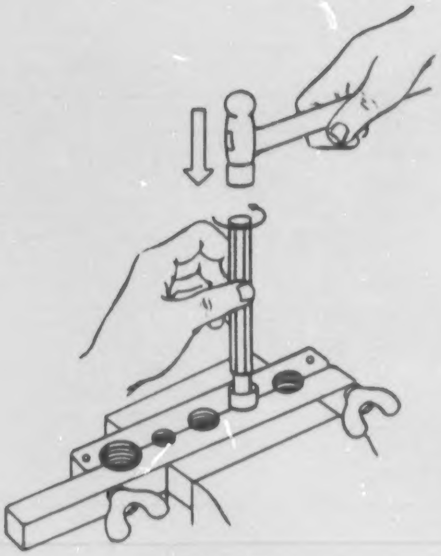

Figure 5

Checked by ______________________
Instructor

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SOFT SOLDERING

OBJECTIVE: To be able to soft solder a sweat fitting.

SETTING UP AND LIGHTING THE TORCH

1. Connect regulator (B), figure 6, to the tank. Tighten the nut securely with a wrench.
2. Connect hose assembly (C) to the regulator and handle.
3. Connect the correct size torch tip (D) to the handle. Tighten the lock-nut finger tight only.
4. Open the tank valve 1/4 turn. Use a tank key and leave it on the tank.
5. Set the pressure adjusting screw for the approximate pressure desired.
6. Light the flame (use a friction lighter).
7. Readjust the regulator pressure adjusting screw to get the desired flame size.
8. To shut off the torch, close the tank valve.

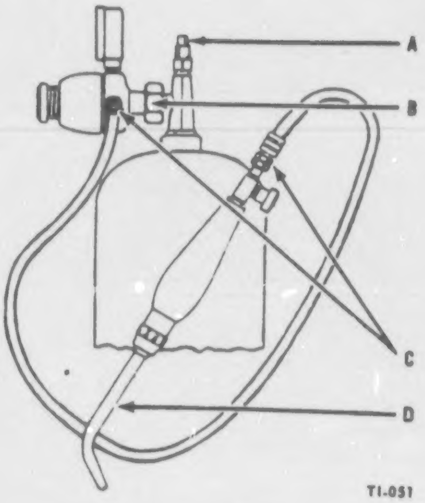

Figure 6

PREPARING COPPER FOR SOLDERING

1. Thoroughly clean both surfaces.

   NOTE: Metal surfaces must be very clean before they will soft solder correctly. The surfaces should be cleaned with steel wool or fine sandpaper. Rough sandpaper or a file may cut into the metal and cause a weak joint.

2. Apply a noncorrosive flux (salve type) to cleaned area.

   CAUTION: This flux is very irritating to the eyes. Do not rub your eyes with fingers after getting flux on them.

   NOTE: Do not apply the flux too thickly as excess flux may form bubbles when heated and prevent the solder from flowing into the joint.

3. After the tube has been inserted into the fitting, revolve it once or twice to spread the flux evenly.

4. Light the hydrocarbon torch and adjust flame for soft soldering.

5. Apply the flame to one side of the fitting.

6. Occasionally test the heat by touching the fitting with the solder.

   CAUTION: Do not let the flame touch the solder.

7. Remove the flame and apply solder to the opposite side of fitting from flame.

   NOTE: The metal must be hot enough to melt the solder.

8. Turn off the hydrocarbon torch.

   NOTE: Most beginning personnel have a tendency to use too much heat and too much solder.

   CAUTION: Lift hot tubing with pliers and cool in water bucket on the workbench.

9. Have the instructor check your work.

Checked by______________________________
Instructor

10. The instructor will have you cut your completed joint to check the condition of the soldered surfaces.

HARD SOLDERING

OBJECTIVE. To be able to hard solder a sweat fitting.

SETTING UP AND LIGHTING THE TORCH

1. Connect regulator (B), figure 7, to the tank. Tighten the nut securely with a wrench.
2. Connect hose assembly (C) to the regulator and handle.
3. Connect the correct size torch tip (D) to the handle. Tighten the locknut finger tightly only.
4. Open the tank valve 1/4 turn. Use a tank key and leave it on the tank.
5. Set the pressure adjusting screw for the approximate pressure desired.
6. Light the flame (use a friction lighter).

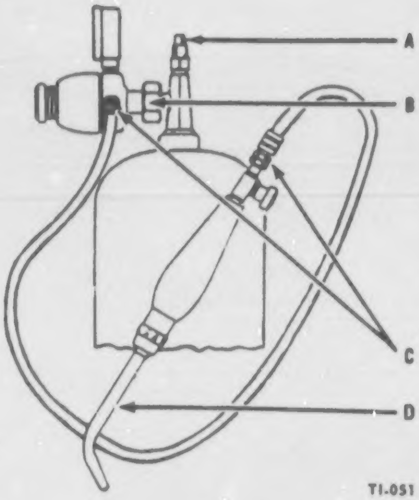

Figure 7

7. Readjust the regulator pressure adjusting screw to get the desired flame size.
8. To shut off the torch, close the tank valve.

PREPARING COPPER FOR SOLDERING

1. Thoroughly clean both surfaces.

   NOTE: Metal surfaces must be very clean before they will solder correctly. The surfaces should be cleaned with steel wool or fine sandpaper. Rough sandpaper or a file may cut into the metal and cause a weak joint.

2. Apply a noncorrosive flux (paste type) to the cleaned areas.

   CAUTION: This flux is very irritating to the eyes. Do not rub your eyes with fingers after getting flux on them

3. After the tube has been inserted into the fitting, revolve it once or twice to spread the flux evenly.
4. Light the hydrocarbon torch and adjust flame for hard soldering.
5. Apply the flame to one side of the fitting.
6. As the copper fitting begins to turn cherry red, touch the hard solder to the fitting on the opposite side from the flame.

   CAUTION: Do not let the flame touch the solder. The metal must be hot enough to melt the solder.

7. Turn off the hydrocarbon torch.

   CAUTION: Lift hot tubing with pliers and cool in water on workbench.

8. Have the instructor check your work.

Checked by ______________________________
Instructor

9. The instructor will have you cut your completed joint to check the condition of the solder surfaces.

ALUMINUM BRAZING

OBJECTIVE: To be able to aluminum braze a sweat fitting.

1. Secure enough aluminum tubing from the roll provided to make six swage connections.

2. After making the swage connections, thoroughly clean the contacting surfaces.

3. Insert the male fitting into the swage after fluxing.

4. Light the hydrocarbon torch and adjust to a soft flame.

5. Apply the flame to the swage joint insuring that you keep the torch moving around the joint.

6. As you apply the heat, place the aluminum brazing rod slightly above the top of the swage joint until the swage has received all the measured amount of melted rod.

7. Turn off the hydrocarbon torch.

   CAUTION: Use pliers to handle hot metal, cool it in the water bucket provided.

8. Cut the completed joint with a hacksaw and check for:

   a. Penetration

   b. Oxidation

9. Have the instructor check your work.

Checked by____________________________
Instructor

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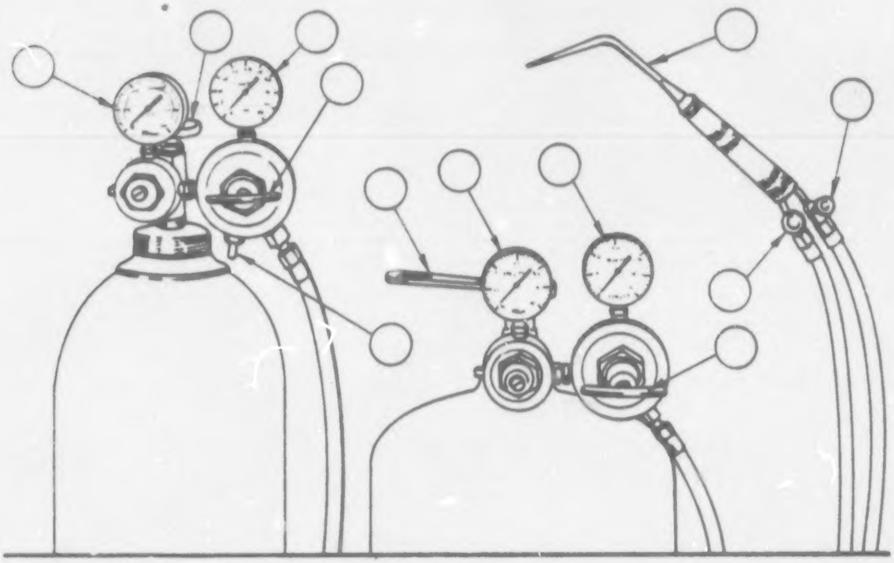
IDENTIFYING OXYACETYLENE EQUIPMENT

OBJECTIVE

To be able to identify oxyacetylene soldering and brazing equipment.

IDENTIFYING UNITS

Identify the parts of the oxyacetylene assembly below by writing in each circle the letter opposite the name of the unit (there are two of some items).



A.	Acetylene Cylinder Valve Wrench	E.	Cylinder Pressure Gages
B.	Blowoff Valve	F.	Oxygen Needle Valve
C.	Torch Tip	G.	Cylinder Hand Valve
D.	Adjusting Key	H.	Regulator Outlet Pressure Gage
		I.	Acetylene Needle Valve

Figure 8. Oxyacetylene Equipment Assembly

2. Fill in the spaces with the required information.

   a. A full cylinder of oxygen should have a pressure of approximately ________.
   ____.

   b. A full cylinder of acetylene should have a pressure of approximately ________.
   ____.

c. What type of oxygen and acetylene regulators are furnished? ____________

____.

d. What material is used in the construction of the torch head and valve body?

____

____

e. All oxyacetylene apparatus and regulators must be free of ______________

________________________ and ________________________________.

PREPARING OXYACETYLENE EQUIPMENT FOR USE

OBJECTIVE: To be able to use safety precautions when handling oxyacetylene equipment, set up and assemble oxyacetylene equipment, and light an oxyacetylene torch.

REVIEWING SAFETY PRECAUTIONS

Study the following safety precautions and observe them as you progress with the steps of this workbook.

1. Refer to oxygen and acetylene by their proper names.
2. Do not use cylinders for supports.
3. Use cylinders in an upright position only.
4. Never use oil or grease on oxyacetylene equipment.
5. Provide for adequate ventilation.
6. Do not release oxygen or acetylene in confined spaces.
7. Do not use acetylene at pressures higher than 15 p.s.i.
8. Turn off regulators before turning on gases from cylinders.
9. Close cylinder valves when leaving for an extended period.
10. Use a friction lighter to light torch.
11. Never leave a burning torch unattended.

ASSEMBLY OF EQUIPMENT

1. Place the oxygen and acetylene cylinders at the end of the workbench with the acetylene in front of the oxygen (see figure 9).
2. Chain the cylinders separately as illustrated in figure 9.
3. Remove the cylinder caps (see figure 9) from both cylinders.

   NOTE: Tight caps may be freed by lightly tapping.
4. Check outlet of both cylinder valves for dust or foreign particles. If present, remove with a non-metallic brush.
5. Attach the oxygen and acetylene regulators to their respective cylinders (see figure 10).

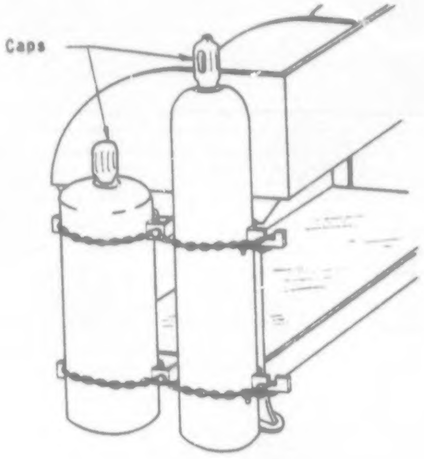


Figure 9. Securing the Cylinders

NOTE: The oxygen regulator connection has right hand threads, and the acetylene has left hand threads.

6. Secure the nuts with the wrench provided with the kit.

7. Attach the oxygen and acetylene hoses to the outlets of their respective regulators (see figure 11).

   NOTE: The oxygen hose connection has right hand threads, and the acetylene has left hand threads.

8. Attach the torch handle to the hoses (see figure 12).

   REMEMBER: Oxygen connections have right hand threads and acetylene has left hand threads.

9. Attach a tip to the torch handle (see figure 13).

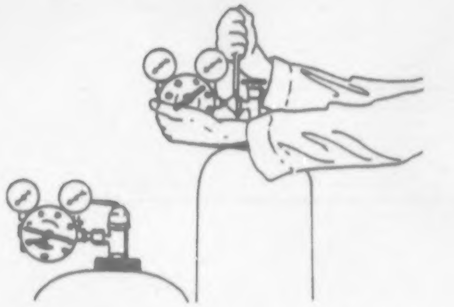


Figure 10. Attaching Regulators

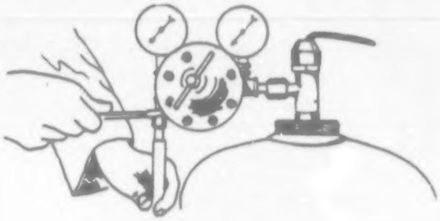


Figure 11. Attaching Hoses

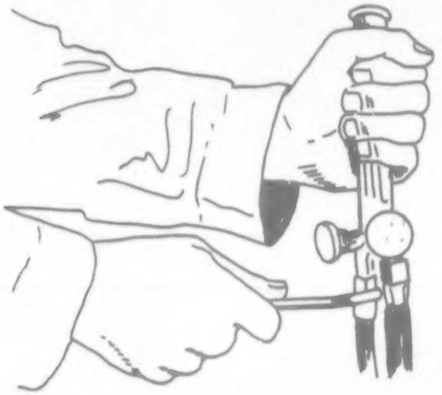


Figure 12. Attaching Handle

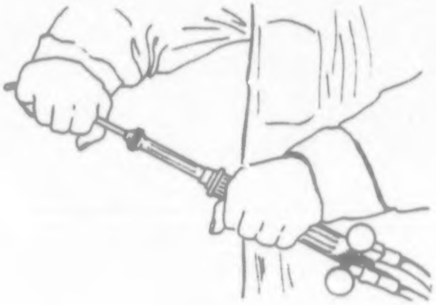


Figure 13. Attach Tip to Handle

TESTING EQUIPMENT FOR LEAKS

1. Close torch handle valves, open cylinder valves, and turn the regulator handles to the right to allow a little pressure to build up.

2. Test all joints for leaks with soap and water (see figure 14).

   NOTE: Leaks can be detected by the appearance of bubbles.

3. Stop all leaks before going any farther.

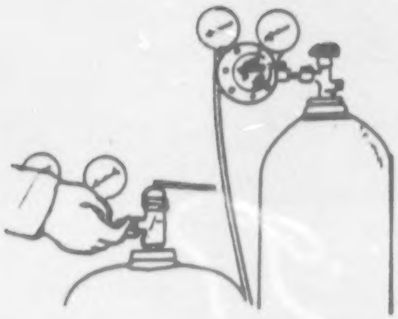


Figure 14. Checking for Leaks

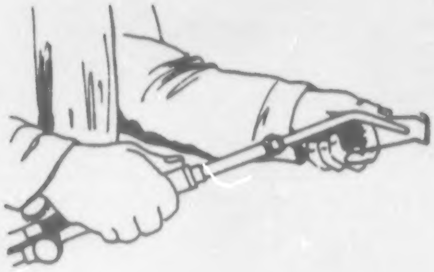


Figure 15. Lighting the Torch

LIGHTING TORCH

1. Adjust regulators to indicate pressures of 1 p.s.i. above tip size.
2. Open the torch handle acetylene valve approximately 1/4 turn.
3. Open torch handle oxygen valve approximately 1/8 turn.
4. Light the gas flowing through the torch tip (see figure 15).
5. Open the acetylene valve until the base of the flame leaves the tip 1/16 inch.
6. Slowly open the oxygen valve until a neutral flame is obtained.

SHUTTING OFF THE ACETYLENE TORCH

1. Shut off the acetylene torch valve.
2. Shut off the oxygen torch valve.
3. Close the acetylene cylinder valve.
4. Open the acetylene torch valve allowing the acetylene to escape from the regulator and hose.
5. Turn the acetylene regulator adjusting screw counterclockwise until it turns easily.
6. Close the acetylene torch valve.
7. Close the oxygen cylinder valve.
8. Open the oxygen torch valve allowing the oxygen to escape from the regulator and hose.
9. Turn the oxygen regulator adjusting screw counterclockwise until it turns freely.
10. Close the oxygen torch valve.
11. Coil the hose, and hang it and the torch on the hook and rack provided for that purpose.

Checked by__________________________
Instructor

WB 3ABR54530-I-5-P6
April 1975

SILVER BRAZING

OBJECTIVE: To be able to light, and adjust the oxyacetylene torch; and to silver braze sweat fittings.

1. Secure enough tubing from the tubing barrel to make six swage connections.

2. After making the swage connections, thoroughly clean the contacting surfaces.

3. Apply a silver soldering flux to the male fitting.

4. Insert the male fitting into the swage and revolve it once or twice to spread the flux evenly.

5. Light the oxyacetylene torch and adjust to a carburizing flame.

6. Apply the flame evenly to one side of the swage bringing it to a cherry red.

   NOTE: Silver solder melts at a temperature of 1000° to 1150° F.

7. Apply the solder to the top of the fitting on the opposite side from flame while applying heat near the bottom of the swage.

   NOTE: If the heat is applied near the bottom of the swage, the solder will be drawn to the bottom.

8. Turn off the oxyacetylene torch.

   CAUTION: Using pliers to handle hot metal, cool it in water bucket.

9. Cut the completed joint with a hacksaw and check for:

   a. Penetration

   b. Excess flux

   c. Oxidation

   d. Excess solder

10. Have the instructor check your work.

Checked by ______________________
Instructor

SILVER BRAZING USING SIL-FOSS

OBJECTIVE: To be able to silver solder a sweat fitting.

1. Secure enough tubing from the barrel to make six swage connections.

   NOTE: Sil-Foss soldering rod contains its own flux and cleaning agent. The tubing does not have to be cleaned or fluxed.

2. Insert the male fitting into the swage.

3. Light the oxyacetylene torch and adjust to a carburizing flame.

4. Apply the flame evenly to one side of the swage, bringing it to a cherry red.

   NOTE: Sil-Foss soldering rod melts at a temperature of around 1250° F.

5. Apply the silver solder rod to the top of the fitting on the opposite side from flame, while applying heat near the bottom of the swage.

   NOTE: If the heat is applied near the bottom of the swage, the solder will be drawn to the bottom.

6. Turn off the oxyacetylene torch.

   CAUTION: Use pliers to lift hot metal and cool in water bucket.

7. Cut the completed joint with a hacksaw and check for:

   a. Penetration

   b. Oxidation

   c. Excess solder

8. Have the instructor check your work.

Checked by___________________________
Instructor

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER II	BLOCK TITLE Electricity

1 COURSE CONTENT	2 TIME
1. Electrical Principles and Circuits	24 (24/0) Days 6 thru 9
a. Using workbook and wiring trainer, connect an operative simple circuit, consisting of a power source, protective device, switch, lamp and an ammeter, observing all applicable safety precautions. STS: 6d(4), 6f, 10a, 10c, 10e(1)(a), 10e(2)(a), 10e(2)(b), 10e(2)(c), 10e(3), 10e(5), 11a Meas: W, PC	(6/0) Day 6

(1) Electrical safety

(2) Definition of voltage and its related factors

(3) Definition of current and its related factors

(4) Definition of resistance and its related factors

(5) Sources of electrical pressure and their requirements

(6) Conductors, insulators and factors that affect conductors

(7) Using the American wire gage chart

(8) Effects of current

(9) Electrical switching and safety devices and electrical symbols

(10) Requirements of simple circuits

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

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COURSE CONTENT

b. Using workbooks and multimeter, measure voltage and resistance on a multimeter trainer to an accuracy of ±5%, observing all applicable safety precautions. STS: 5b, 5d, 6d(4), 10a, 10d, 10g(1) Meas: W, PC — (6/0) Day 7

(1) Factors relating to magnetism

(2) Purpose and application of the voltmeter, ammeter, and ohmmeter

(3) Safety precautions when using meters

c. Using workbook and wiring trainer, construct an operative series and parallel circuit. Using multimeter, apply Ohm's law and circuit characteristics to find the unknown factors of each circuit, observing all applicable safety precautions. STS: 5f, 6d(4), 10a, 10b, 10e(1)(b), 10e(1)(c), 10g(1) Meas: W, PC — (6/0) Day 8

(1) Ohm's law and the operating characteristics of a series circuit

(2) Ohm's law and the operating characteristics of a parallel circuit.

d. Using workbook, multimeter and electrical trainer, locate 100% of the opens, shorts and mechanical malfunctions, observing all applicable safety precautions. STS: 6d(4), 10e(6), 10g(1), 10g(2), 10g(3), 10g(5) Meas: W, PC — (6/0) Day 9

(1) Troubleshooting a circuit to locate opens

(2) Troubleshooting a circuit to locate shorts

(3) Troubleshooting a circuit to locate low power and mechanical malfunctions

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-II-1, Electrical Principles and Direct Current Circuits
WB 3ABR54530-II-1-P1, Identifying Electrical Units and Circuits
WB 3ABR54530-II-1-P2, Multimeter Reading
WB 3ABR54530-II-1-P3, Wiring a Series Circuit
WB 3ABR54530-II-1-P4, Wiring a Parallel Circuit
WB 3ABR54530-II-1-P5, Circuit Analysis
2TPT3100-04, Electrical Fundamentals (Remedial)
2TPT3101-07, Basic Electricity, Ohm's Law, and DC Power
2TPT3101-08, D.C. Series Circuits (Remedial)
2TPT3101-09, Parallel D. C. Circuits (Remedial)

Audio Visual Aids
Chart Set, Electrical Meters
Transparencies, Set, Electrical Principles
Training Film: TF-6081, Basic Electricity

Training Equipment
Trainer, Fundamental Electrical Principles (12)
Trainer, Multimeter Reading (1)
Trainer, Multimeter (12)
Trainer, Electrical Circuits (1)
Trainer, Electrical Circuits and Meters Reading (1)
Bench Item, Galvanometer (12)
Bench Item, Rectifier (12)
Bench Item, Dynamo, Hand-Operated (12)
Multimeter (1)

Training Methods
Discussion/Demonstration (8.5 hrs)
Training Film (0.5 hr)
Performance (15 hrs)

Multiple Instructor Requirement
Safety, Equipment, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions involved in use of electrical test equipment and on careful handling of delicate and expensive test equipment.

MIR: Two instructors required for 12 hours during student performance (4 hours in Day 7, 4 hours in Day 8, and 4 hours in Day 9).

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
II	Electricity

1 COURSE CONTENT	2 TIME
2. Alternating Current Wiring Systems	22 (18/4) Days 10 thru 12
a. Using the workbook, identify operating characteristics of a. c. circuits containing capacitance and inductance. STS: 10a Meas: W	(6/0) Day 10
(1) Differences between a. c. and d. c. electricity	
(2) Frequency, cycle, alternation, and sine wave	
(3) Coil in an a. c. circuit	
(4) Capacitor in an a. c. circuit	
(5) Single-phase transformers	
b. Using wiring trainer, connect 110V, 220V single-phase and 220V three-phase components to a power supply, observing workbook requirements and safety precautions. STS: 6d(4), 10e(4), 10e(5) Meas: W, PC	(6/2) Day 11
(1) Wye-type three-phase transformer and the two-, three-, and four-wire system	
(2) Safety precautions pertaining to wiring	
c. Using wiring trainer, install, wire, check and service a motor starter, observing workbook requirements and safety precautions. STS: 6d(4), 10f(6), 10f(7), 10f(8) Meas: W, PC	(3/1) Day 12
(1) Purpose of the across-the-line motor starter	
(2) Parts of the across-the-line motor starter	

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

d. Using wiring trainer, install, wire, check, and service a motor, observing workbook requirements and safety precautions. (3/1) Day 12
STS: 6d(4), 10f(1), 10f(2), 10f(3), 10f(5), 21b(2), 21b(3).
Meas: W, PC

(1) Major components of motors

(2) Principles of operation and application of electric motors

(3) Maintenance of electric motors

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-II-2, Alternating Current Wiring Systems
WB 3ABR54530-II-2-P1, Characteristics of Alternating Current Circuits
WB 3ABR54530-II-2-P2, Checking Voltage on Three-Phase Transformers
WB 3ABR54530-II-2-P3, Making Pigtail Splices
WB 3ABR54530-II-2-P4, Wiring 220-Volt, Four-Wire Systems
WB 3ABR54530-II-2-P5, Wiring the Across-the-Line Motor Starter
WB 3ABR54530-II-2-P6, Operating Characteristics and Wiring of Induction Motor

Audio Visual Aids
Charts, Set, Alternating Current Generation
Transparencies, Set, Alternating Current Wiring Systems

Training Equipment
Trainer, Electric Motor and Three-Phase Wiring Operation (12)
Trainer, Motor Starter (12)
Trainer, Motor and Motor Starter (2)
Multimeters (1)
Bench Item, Dynamo, Hand-Powered (12)
Multimeter, Amp-Probe/Voltmeter (12)

Training Methods
Discussion/Demonstration (11 hrs)
Performance (7 hrs)
CTT Assignment (4 hrs)
Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

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Instructional Guidance

Place adequate emphasis on safety precautions involved in use of electrical test equipment and on careful handling of delicate and expensive test equipment. Outside Assignment: Day 11, direct students to review WBs II-2-P1 thru P4; Day 12, P5 and P6.

MIR: Two instructors are required for 4 hours during student performance in Day 11.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
II	Electricity

1 COURSE CONTENT	2 TIME
3. Electrical Troubleshooting	22 (16/6) Days 13 thru 15
a. Using workbook, multimeter and troubleshooting trainer, locate 100% of the opens, shorts, and low power conditions on the 120V single-phase and 220V three-phase circuits, observing safety precautions. STS: 6d(4), 10e(6), 10g(1), 10g(2), 10g(3). Meas: W, PC (1) Troubleshooting procedures (2) Safety precautions when troubleshooting a.c. circuits	(6/2) Day 13
b. Using workbook, multimeter, and troubleshooting trainer, locate 100% of the opens, shorts, and low power conditions on the 208V single-phase circuit, observing safety precautions. STS: 5f, 6d(4), 10e(6), 10g(1), 10g(2), 10g(3). Meas: W, PC (1) Troubleshooting procedures (2) Safety precautions when troubleshooting a.c. circuits	(6/2) Day 14
c. Using workbook and wiring schematic, apply Ohm's law and circuit characteristics to determine the unknown factors. STS: 10e(6). Meas: W, PC (1) Circuit characteristics (2) Tracing line and low-voltage circuits	(4/2) Day 15

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-II-3, Electrical Troubleshooting
WB 3ABR54530-II-3-P1, Troubleshooting Single-Phase 120 Volt Circuit
WB 3ABR54530-II-3-P2, Troubleshooting three-Phase Circuits
WB 3ABR54530-II-3-P3, Troubleshooting 208-Volt Single-Phase Circuits
WB 3ABR54530-II-3-P4, Electrical Blueprint Reading and Trouble Analysis
2TPT3100-06, Troubleshooting (Opens, Shorts, Grounds and Low Power)

Audio Visual Aids
Charts, Set, Electrical Troubleshooting
Transparencies, Set, Electrical Troubleshooting

Training Equipment
Trainer, A. C. Troubleshooting (2)
Multimeters (2)

Training Methods
Discussion/Demonstration (4 hrs)
Performance (12 hrs)
CTT Assignment (6 hrs)

Multiple Instructor Requirement
Safety, Equipment, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions involved in the use of electrical test equipment. Emphasize careful handling of delicate and expensive test equipment. Outside Assignment: Day 13, direct students to review WBs II-3-P1; Day 14, P2; Day 15, P3 and P4.

MIR: Two instructors are required for 9 hours during student performance (4.5 hours in Day 13 and 4.5 hours in Day 14).

4. Related Training (identified in course chart) 10

5. Measurement Test and Test Critique 2
(2/0)
Day 15

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STUDY GUIDE 3ABR54530-II-1

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

ELECTRICAL PRINCIPLES AND DIRECT CURRENT CIRCUITS

April 1975

SHEPPARD AIR FORCE BASE

11-6

Designed For ATC Course Use

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-II-1
28 September 1973

ELECTRICAL PRINCIPLES AND DIRECT CURRENT CIRCUITS

SECTION I

DIRECT-CURRENT ELECTRICITY

OBJECTIVE

This study guide will aid you in becoming familiar with:

* THE PRINCIPLES OF ELECTRICITY

* THE SYMBOLS AND TERMS PERTINENT TO ELECTRICITY

* THE TYPES AND OPERATION OF ELECTRICAL METERS

* THE TYPES AND CHARACTERISTICS OF ELECTRICAL CIRCUITS

* ELECTRICAL TROUBLE ANALYSIS PROCEDURES

INTRODUCTION

Stop for one moment and try to imagine that there is no electricity around you. What would be missing? Lights, fan, radio, TV, razor, stove, toaster, refrigerator, washing machine, telephone, air conditioner? The list seems almost endless when you think of all the electrical devices that seem so common.

Have you ever wondered just what happened when you turned on the switch? Or, why nothing happened when you turned on the switch? In this text you will find the answers to both of these questions.

You may question why a refrigeration specialist studies electricity. The answer is simple. It will be your job to determine whether a refrigeration malfunction is caused by the refrigeration system or the electrical system. Approximately three-fourths of all refrigeration malfunctions are caused by electrical troubles. Therefore, a fundament knowledge of electricity will be essential in doing your job.

CONSTRUCTION OF MATTER

To understand the nature of electricity, a discussion of matter is necessary. All matter, such as metals, water, rubber, and air, is made of small particles called molecules. (See figure 1.)

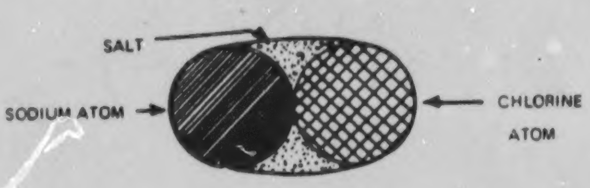


Figure 1. Molecule of Salt

Molecules

A molecule is the smallest particle of any compound that can exist and still have the same substance. For example, a molecule of salt is the smallest particle of salt that can exist and still be salt. Let us examine a single molecule of salt more closely. If we were to divide this one molecule of salt, we wouldn't have salt any more. We would have one atom of sodium and one atom of chlorine.

Atoms

Atoms are so small that two hundred million of them of them placed side by side would only measure one inch. In spite of this, we have a very clear idea of what goes on inside an atom.

Construction of an Atom

You may be familiar with the fact that the earth rotates around the sun in a path called an orbit. (See figure 2.) The relationship of the sun and earth is known as the solar system. The sum is the core and the earth is one planet of the system.

An atom is constructed in a manner which greatly resembles the solar system of the sun and the earth. Each atom has a core (like the sun) and one or more planets (like the earth) revolving about it.

The hydrogen atom is the simplest of all atoms. It has just one planet revolving about its core. (See figure 3.) In an atom, the planets are called electrons (negatively charged particles).

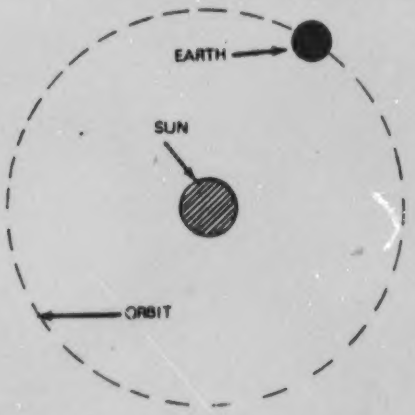


Figure 2. Solar System

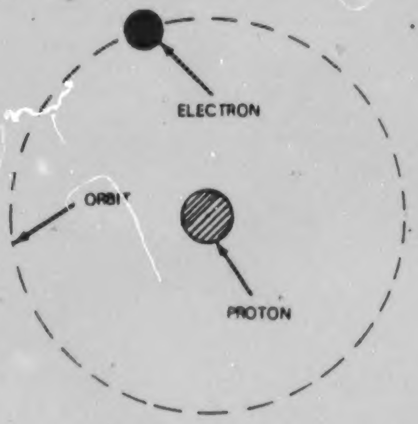


Figure 3. Hydrogen Atom

These electrons, together with protons (positively charged particles) and neutrons (neither positive nor negative), make up the atoms of which matter is composed. The electrons are in constant motion about the nucleus. (See figure 4.)

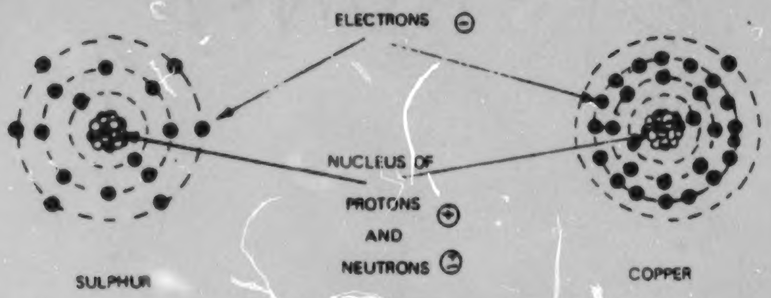


Figure 4. Construction of an Atom

Some of these electrons are loosely held by the nucleus and will move freely when an electrical pressure is applied. The uniform flow of these electrons is called electric current. If a substance has a large number of free electrons and allows current to flow easily, the substance is called a conductor. Other substances, such as mica, glass, and rubber have few free electrons and prevent the movement of their electrons. These substances are called insulators.

ELECTROMOTIVE FORCE

We are all familiar with the fact that it takes pressure to push water through a hose. In the city water system we have 60 psi. This pressure will push a certain amount of water through a 1/2-inch garden hose.

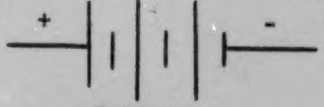
It is understandable, then, that to have electricity we must first produce electrical pressure which will force the electrons through the wires and through the electrical appliance. This pressure is called electromotive force, voltage, or difference in potential. These terms have the same meaning.

Electrical pressure is obtained by converting heat, mechanical and chemical energies into electrical energy. The battery on your car is an example of chemical energy which is converted into an electrical energy. The main source of voltage, however, is the conversion of mechanical energy into electrical energy, as in the case of the generator. To generate a voltage mechanically, three things are needed. You must have a conductor, a magnetic field, and relative motion. Combine these three, move the conductors or magnetic field, and voltage will be generated.

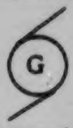
Electrical devices are represented in symbol form. Symbols are a shorthand method of representing the unit; they save time and space. The symbols for a battery and generator can be seen in figure 5.

Some facts about voltage that you should remember are:

- The unit of measure for electromotive force (EMF) is the VOLT.
- EMF is measured with a VOLTMETER.
- The SYMBOL for EMF is "E."
- The EFFECT OF EMF is that it causes CURRENT to flow.



Battery



Generator

Figure 5. Symbols

CURRENT

The word "current" means motion or movement. Current is the uniform movement of electrons. (The pressure which moves them has already been explained.)

Let's examine a piece of copper wire. The wire appears to be a solid piece of material; however, this wire, as you have learned, is made up of millions and millions of electrons. If one extra electron is pushed into one end of the wire, the atom has an extra electron. It will now push this extra electron over to the next atom. This atom will repeat the process until the end of the wire is reached. At the end of the wire the electron will jump to any other object that needs an electron. This is what is happening when you see an electric "spark." The magnified section of copper wire shown in figure 6, illustrates the movement of electrons along the wire. If they flow in only one direction it is said to be direct current (dc).

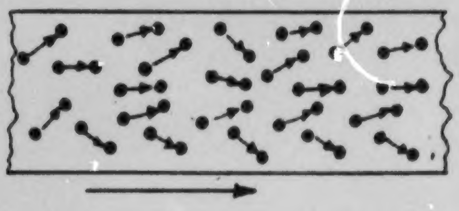


Figure 6. Direction of Electron Flow

It is very easy to measure the amount of water flowing in a water system. This might be one gallon per second or 50 gallons per second. Where water flow is measured by the gallon, electron flow is measured by the ampere. In the simplest form, an ampere is 6,280,000,000,000,000,000 electrons passing a given point in one second. Of course, this figure is not used in practical application, but it does prove that an ampere is a given amount. The symbol for current is "I." The meter used to measure electron flow is the ammeter ($^+$ A $^-$).

The movement of electrons through a conductor will cause four different effects.

First, current always causes HEAT. The amount of heat produced depends on the amount of current flowing and the material of the conductor. Copper conductors give very little rise in temperature, while nichrome is used in heating elements. The conversion of electrical energy into heat is used in such devices as electric lights, stoves, and soldering irons. (See figure 7.)

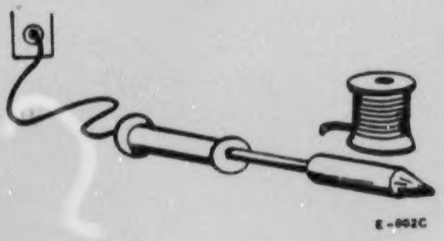


Figure 7. Heat

A second effect of current is CHEMICAL CHANGE (figure 8). As current passes through impure water it causes a chemical change. An example of this is the breaking down of water into oxygen and hydrogen. This effect of current is also used to plate metals. Another use of chemical change is to charge batteries.

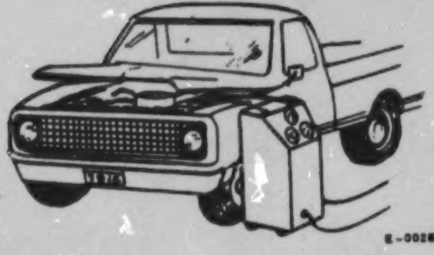


Figure 8. Chemical Change

A third effect of current is SHOCK (figure 9). As current passes through the body it produces an effect known as "physical shock." Hospitals use this in the treatment of some illnesses. It has no useful purpose as far as the refrigeration serviceman is concerned; however, it can cause death if you become careless. Under ideal conditions 1/10 of an amp can kill you!

Figure 9. Physical Shock

A fourth effect of current is MAGNETISM (figure 10). Magnetism means the ability to attract iron. Copper will not magnetize but current through a copper wire will set up a magnetic field about the wire. This magnetic effect of current is used in electrical motors, generators, and electromagnets.

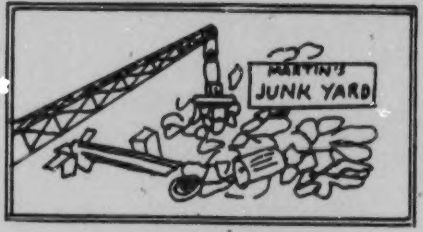


Figure 10. Magnetism

RESISTANCE

The opposition to the flow of current offered by the conductors and electrical appliances is called resistance. The OHM (Ω) is the unit of measure for resistance. The meter used to measure resistance is the OHMMETER (-Ⓞ-).

There are four factors which affect the resistance of a conductor.

One factor affecting resistance is LENGTH. Referring again to the water system, if we had a hose 50 feet long, we would expect a lot of water to flow through it. If the length of the hose were increased to 100 feet, what would happen to the flow? The same thing happens in an electrical conductor. The longer the wire, the higher the resistance and the less current will flow through it. (See figure 11.)

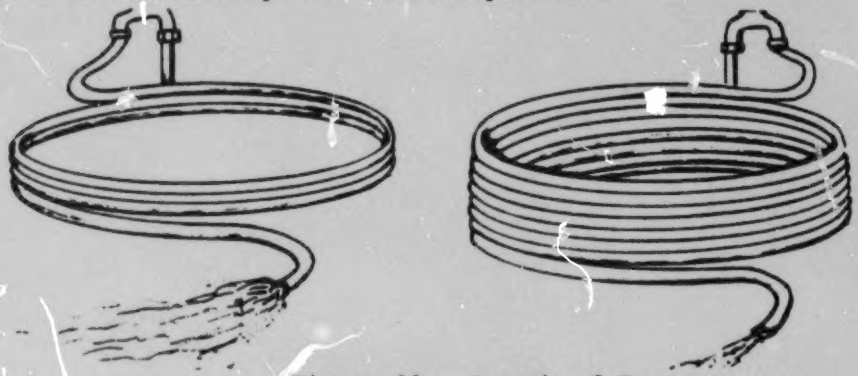


Figure 11. Length of Hose

A second factor affecting resistance is AREA or DIAMETER. Both the hoses in figure 12 are the same length, but the diameter of one is twice that of the other.

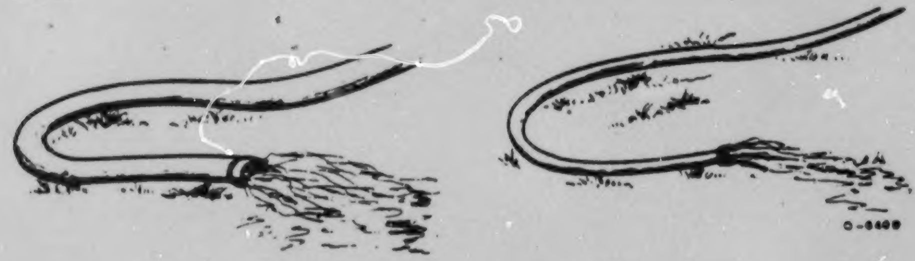


Figure 12. Diameter of Hose

The larger hose would naturally be expected to deliver a larger flow of water. The same thing happens in an electrical conductor. The larger the area of the conductor, the greater the flow of electrons.

The third factor affecting resistance is MATERIAL. Any substance in which an electrical pressure can separate large quantities of electrons from their atoms and force these electrons to move in the substance is a good conductor. (Silver is one of the better conductors.) When the material of a conductor is changed, the resistance of the conductor changes.

The fourth factor affecting resistance is TEMPERATURE. Temperature is the speed of the molecules in a substance. If the molecules are moving, the atoms are also moving. If the temperature of the conductor increases, the speed of the atoms increases. This increase in speed makes it more difficult for voltage to separate the electrons from their atoms; consequently, current decreases.

Basic electrical factors can be seen in figure 13.

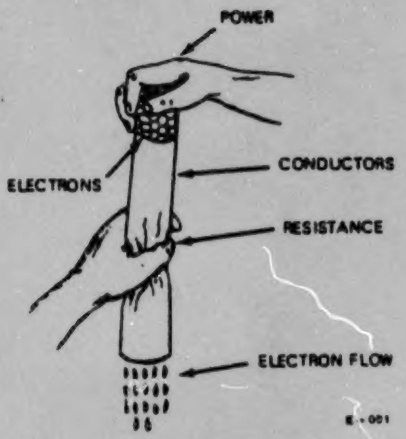

POWER
CONDUCTORS
ELECTRONS
RESISTANCE
ELECTRON FLOW
E-001

Figure 13. Basic Electrical Factors

AN ELECTRICAL CIRCUIT

An electrical circuit is a closed path in which electrons can flow. The four basic requirements of a circuit are (1) negative conductor, (2) positive conductor, (3) source of power, and (4) unit of resistance.

The negative conductor is the connection made from the negative terminal of the source of power to the unit of resistance.

The positive conductor is the connection made from the unit of resistance to the positive terminal of the source of power.

The source of power or voltage is usually a chemical or mechanical energy converted into electrical energy.

The unit of resistance is the opposition placed in the path of current, such as a light, fan, motor, or refrigerator.

The four basic parts of the circuit can be seen in figure 14.

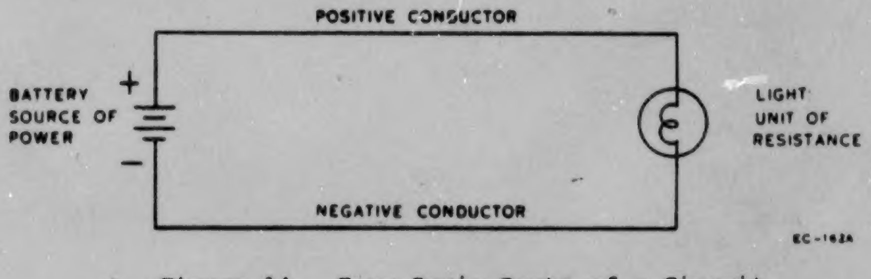

POSITIVE CONDUCTOR
BATTERY SOURCE OF POWER
+
−
LIGHT UNIT OF RESISTANCE
NEGATIVE CONDUCTOR
EC-162A

Figure 14. Four Basic Parts of a Circuit

In figure 15 are three illustrations of circuits containing resistance.

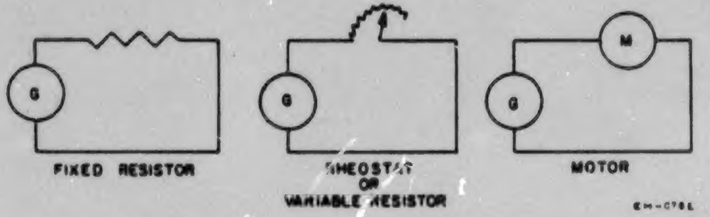


Figure 15. Resistance

The circuit for safety and convenience should contain protective devices and control devices.

CIRCUIT PROTECTIVE DEVICES

It is reasonable to state that if nothing were to oppose the movement of electrons, there would be excessive current flow. The correct resistance and pressure in the circuit will maintain safe and correct current flow. However, malfunctions may occur, such as the negative conductor, coming in direct contact with the positive conductor. (see figure 16).

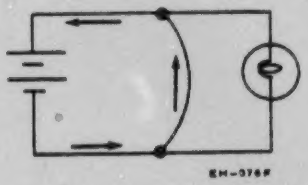
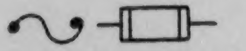


Figure 16. Negative Conductor Touching a Positive Conductor

In figure 16, the arrows show the current taking the path of least resistance. With no opposition in the path of the electrons, the current will increase. You have learned that current causes heat. In figure 16 there is nothing to burn but wires.

To protect the circuit there are various circuit protectors, such as fuses and circuit breakers.

Fuses 

A fuse is a strip of metal with a very low melting point, connected in the circuit so that all current in the circuit must flow through it. (See figure 17.)

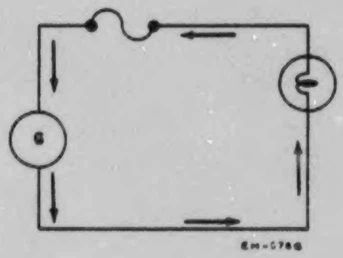
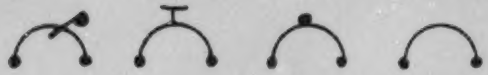


Figure 17. All Current Flows Through the Fuse

An alloy of tin and bismuth is used in most fuses. A fuse will melt and break the circuit whenever the current becomes excessive.

Since a fuse is a protective device, it is important to use one that fits the needs of the circuit in which it is to be used.

Circuit Breakers



A circuit breaker is a device that breaks the circuit when the current reaches a predetermined value. The feature which distinguishes a circuit breaker from a fuse is that a circuit breaker can be reset while a fuse must be replaced. The circuit breaker is connected in the circuit in the same manner as the fuse.

Circuit breakers, like fuses, must be the weakest part of the circuit. They contain a strip of metal that will move when heated. This strip of metal acts as a lock to hold a spring-loaded switch closed. As the current flow increases, it heats the metal strip; this causes the metal strip to move enough to allow the spring-loaded switch to open. After cooling, circuit breakers can be reset.

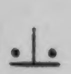
As a matter of safety, never use a coin in place of a protective device. The wiring will become the weakest point. As the current increases, the wire will become hot and a fire may be started inside the walls of the building. An oversized fuse will have the same effect.

The rating of the circuit protective device (fuse or circuit breaker) is determined by the wire size, or current carrying capacity. Heat is one of the effects of current. As current increases, temperature of the conductor increases. The following table shows the American Wire Gauge sizes and amperages for conductors. The amperages are the maximum for the conductors listed. An increase beyond the maximum listed ratings creates excessive heat. Fuse or circuit-breaker amperages should never be larger than the wire is capable of carrying. For conductor amperage capacities in conduit or special applications, consult the National Electrical Code.

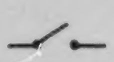
Conductor Size AWG	Maximum Current Capacity (for Rubber Insulation
16	6
14	15
12	20
10	25
8	35
6	50
4	70
2	90

CONTROL DEVICES

To conveniently open or close the circuit, several types of control devices may be used in electrical circuits.

Push Button 

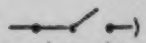
A switch of this type is also used to control the light in the household refrigerators.

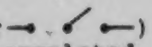
Knife 

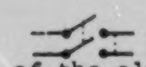
The knife switch consists of a movable metal bar with an insulated handle. It is used as a safety device at the electrical entry. Opening this switch will stop the flow of electricity to an area of the building.

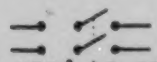
Types

The different types of knife switches can be identified by the number of poles and throws. The pole of a switch refers to the movable contactor, and the throw refers to the circuit or circuits which the pole can complete.

The single pole, single-throw (SPST or ) switch has one movable contactor and can complete only one circuit.

The single-pole, double-throw (SPDT or ) switch has one movable contactor and two circuits can be completed, but only one at a time.

The double-pole, single-throw (DPST or ) switch has two movable contactors and can open both lines of the electrical circuit.

The double-pole, double-throw (DPDT or ) switch has two movable contactors. This switch is used to control a motor where the direction of rotation needs to be changed often. On one position, the motor will run clockwise; in the other position, it will run counterclockwise. This type switch is also used to control a two-speed motor.

Toggle

This type switch has a toggle that can be moved back and forth to open or close the circuit. Types of toggle switches and their symbols are the same as for the knife switch. Toggle switches are normally used to control lights in a room. Figure 18 shows the wiring of switches in a circuit. In illustration "A" the switch is in the OFF position in illustration "B" the switch is in the ON position.

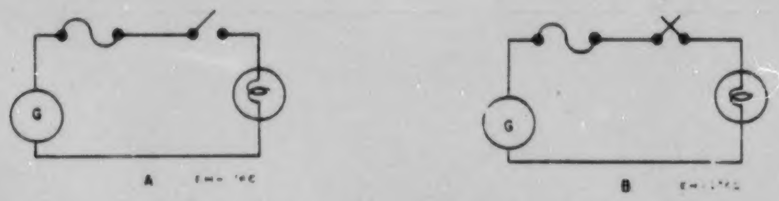


Figure 18. Switch Positions

Relay

The relay switch operates on the principle of electromagnetism. A solenoid consists of a coil of wire wound around a hollow cylinder. It is used to produce a magnetic field. When a movable core of soft iron is placed inside the hollow cylinder, the field of the coil will tend to center the core into the coil when there is current. Solenoid coils with movable cores are used in many controls (such as line starters) in refrigeration and air-conditioning units.

SUMMARY

Current is the flow of electrons in a closed path. They are forced to flow by applying an electrical pressure. Resistance is the opposition to the flow of electrons.

Four effects of current are heat, magnetism, shock, and chemical change.

Heat, chemical, and mechanical energies can be converted to electrical energy.

Resistance of a conductor is affected by length, size, temperature, and material.

A circuit is a closed path for electrons to flow from a source of pressure, through resistance, and back to the source of pressure.

Fuses and circuit breakers are used to protect the circuit in case of an overload.

Switches are used to control the circuit conveniently.

QUESTIONS

1. What is current?
2. Name an effect of electromotive force.
3. List three effects of current.
4. What are two factors that affect resistance?
5. What is an ohmmeter used to measure?
6. What is the unit of measure for voltage?
7. What is the symbol for current?
8. Name the three things necessary to generate voltage mechanically.
9. Name three methods by which an electrical pressure can be produced.
10. What is the purpose of a voltmeter?

SECTION II

MAGNETISM AND METERS

INTRODUCTION

Practically all electrically equipment with which you will be working will depend on the action of magnetic fields. In this section of the study guide, magnetism as it is used in electrical measuring instruments will be discussed. The latter part of the study guide will deal with the use of the meters.

PRINCIPLES OF MAGNETISM

A magnet is an object which has the ability to attract iron. Any object which acquires magnetism when placed in a magnetic field is said to be magnetized. Before an object (such as a steel bar) is magnetized, the molecules point in all directions, as shown in figure 19.

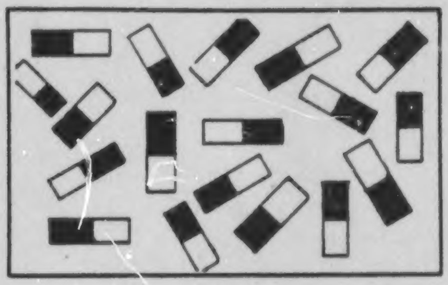


Figure 19. Arrangement of Molecules in an Unmagnetized Steel Bar

When the steel bar is placed in contact with a magnet. The molecules will be rearranged as in figure 20. The steel bar is said to be magnetized, and thus becomes a magnet.

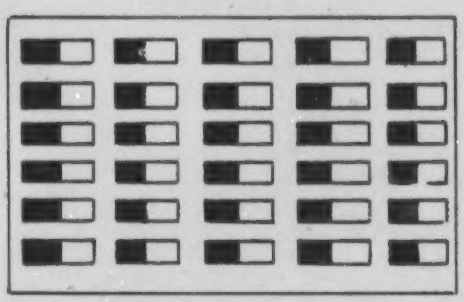


Figure 20. Arrangement of Molecules in a Magnet

It is easy to arrange the molecules of soft iron. But when the magnetizing force is removed, its molecules will return to the position shown in figure 19. However, in hard steel, arranging the molecules is more difficult, but the molecules remain alined.

We can conclude from this that there are two types of magnets, and soft iron is used in making temporary magnets.

In any magnet the ends are called the magnetic poles (north and south). If a magnet is cut into pieces each piece becomes a separate magnet with a north and south pole (See figure 21.)

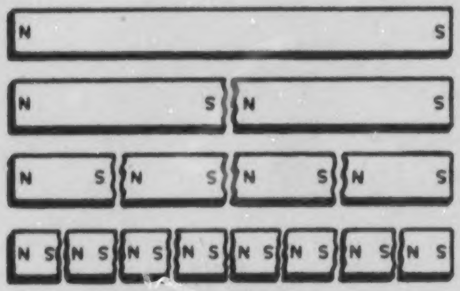
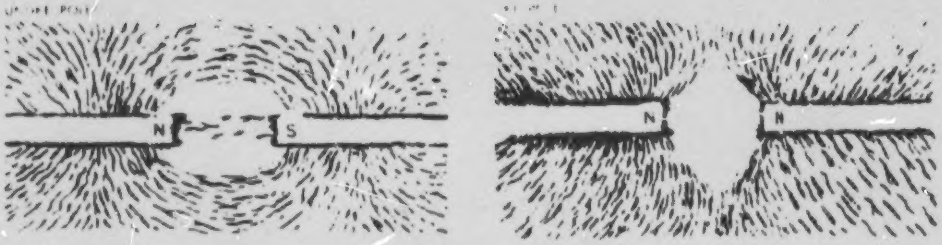


Figure 21. Breaking a Magnet Makes Each Piece a Small Magnet

If two magnets are suspended and are free to move, their like poles will repel each other, and their unlike poles will attract each other. (See figure 22.)



Unlike Poles Attract

Like Poles Repel

Figure 22. Attraction and Repulsion

Lines of Force

The space around a magnet in which its force may be detected is its MAGNETIC FIELD. The magnetic field is made up of LINES OF FORCE. (See figure 23.)

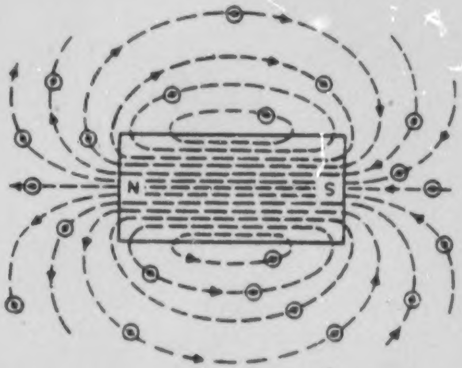


Figure 23. Magnetic Field Around a Bar Magnet

When the theory of the magnetic force was proposed, it was believed that magnetic loops, or lines, emerged from N poles and entered S poles as shown in figure 23. The theory founded upon this belief has never been disproved.

Although you cannot see a magnetic field, you can prove that one does exist by placing a bar magnet under a piece of plastic or white paper and sprinkling iron filings on top of the paper as shown in figure 24.

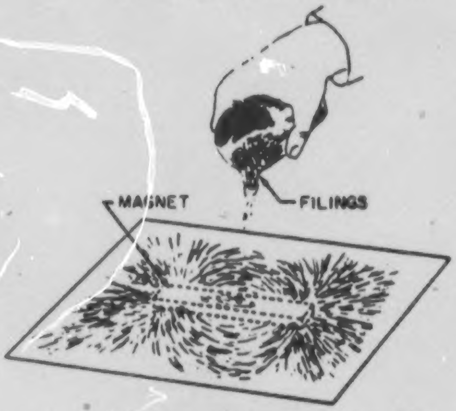


Figure 24. Pattern of Lines of Force

This experiment also proves that magnetic lines of force can pass through plastic or paper. They will pass through all substances, including air. In fact, there is no known substance that will insulate magnetic lines of force.

When a piece of soft iron is placed in the air between the poles of a magnet, the magnetic lines will take the path of least resistance. Consequently, the lines will pass through the piece of iron rather than the air. (See figure 25.)

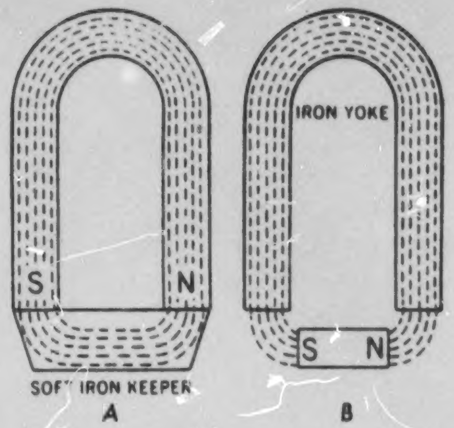


Figure 25. Effects of Soft Iron Bar on a Magnetic Field

Magnetic Induction

When an unmagnetized bar is placed within the magnetic field of another magnet, the lines of force will pass through the unmagnetized bar (see figure 26), alining its molecules. When the molecules are alined, magnetism results. This is called induced magnetism. When magnetism is induced into an unmagnetized object, it will assume a polarity that is the reverse of the magnetising force.

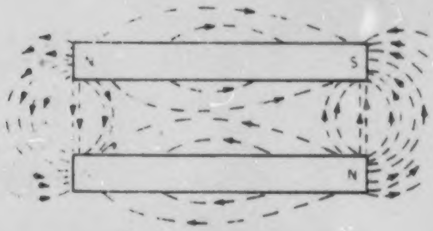


Figure 26. Induced Magnetism

Electromagnetism.

Magnetic fields are also produced by electric current. (See figure 27.) Such fields are called electromagnetic fields and are composed of lines of force like all other magnetic fields. The force of the field is strongest close to the wire or conductor.

117

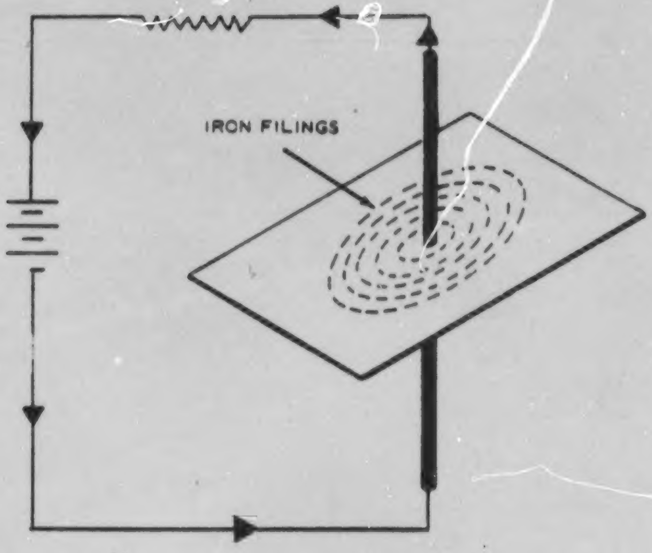

IRON FILINGS

Figure 27. Magnetic Lines of Force Around a Current Carrying Wire

A stronger magnetic field can be obtained by looping the conductor to form a coil as shown in figure 28.

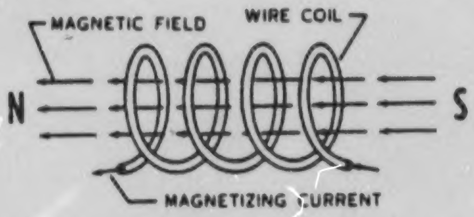

MAGNETIC FIELD
WIRE COIL
N
S
MAGNETIZING CURRENT

Figure 28. A Current Carrying Coil has a Magnetic Field

If the coil is wrapped around a bar of iron as in figure 29, the magnetic field becomes still stronger. This is because iron, as has already been stated, offers an easier path for magnetic lines of force than does air, and because the bar becomes magnetized and its lines of force add to those of the coil. The iron bar becomes an electromagnet having polarity and all the characteristics of any other magnet.

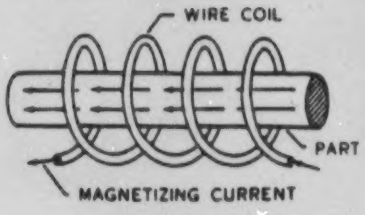

WIRE COIL
PART
MAGNETIZING CURRENT

Figure 29. The Electromagnet

Left-Hand Rule

The left-hand rule for determining the polarity of a coil is illustrated in figure 30.

If you place your fingers around the coil, pointing in the direction of electron flow through the conductor, the thumb will point to the north pole of the coil. It is understandable that reversing the current flow through the conductor will reverse its polarity.

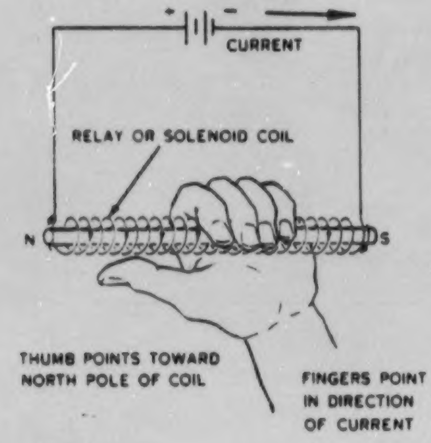

+
-
CURRENT
RELAY OR SOLENOID COIL
N
S
THUMB POINTS TOWARD NORTH POLE OF COIL
FINGERS POINT IN DIRECTION OF CURRENT

Figure 30. Left-Hand Rule for Determining Polarity of an Electromagnet

Three things determine the strength of an electromagnet:

Material in the core.

Number of turns in the coil

Amount of current through the coil.

As long as current flows in the conductor, the lines of force surround it. But when the current ceases to flow, the lines collapse and the iron bar loses its magnetism. Therefore, it is called a temporary magnet.

With an understanding of magnetism, you are now ready to study the operation of meters.

DC METERS

The refrigeration specialist needs to know how to use the voltmeter to measure the difference in electrical pressure, the ammeter to measure the current flow, and the ohmmeter to measure resistance. All of these meters use a permanent magnet and an electromagnet in their meter movement.

Meter Movement

The D'Arsonval meter movement consists of an electromagnet rotating in the field of a permanent magnet. (See figure 31.)

The current enters at terminal "C" and causes coil "AB" to become an electromagnet. By applying the left hand rule for coils, you can see that "B" is the north pole and "A" is the south pole. Since unlike poles attract, "A" will be attracted by the north pole of the permanent magnet and "B" will be attracted by the south pole of the magnet, causing the coil to rotate clockwise and the pointer to move clockwise. If the amount of current through the coil is increased, naturally the magnetic field becomes stronger and the amount of rotation will increase.

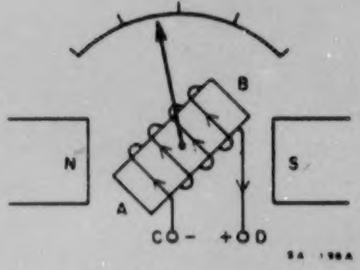
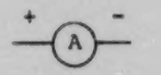


Figure 31. Schematic Drawing of the D'Arsonval Meter Movement

If the direction of current flow is reversed, the coil tends to rotate counterclockwise. Therefore, dc voltmeters and ammeters must be connected into the circuit with proper polarity. The terminals of these meters have their polarity marked.

DC Ammeter



The ammeter is used to measure the amount of current flow in the circuit. Consequently, it will be connected in series with the operating unit as shown in figure 32.

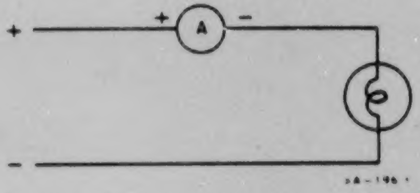


Figure 32. Ammeter Connected in Series with the Unit

The coil of the meter movement is not always capable of carrying the current flow of the circuit. In order to enable the ammeter to measure a greater rate of current flow, it is only necessary to add a bypass for current or a shunt. A shunt is a strip of metal having low resistance. It is connected across the meter terminals to carry most of the current. It allows only a small part of the current to flow thourgh the coil. The shunt may be inside the meter case or it may be connected externally. (See figure 33.)

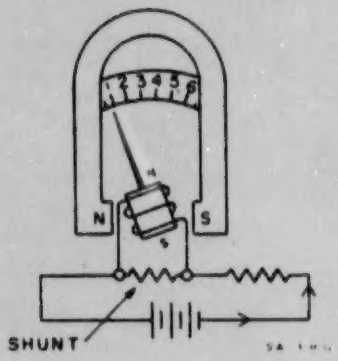


Figure 33. Ammeter Construction

Remember:

An ammeter is connected in series with the unit.

Connect the positive terminal of the ammeter toward the positive side of the circuit. (See figure 32.)

Know the ammeter current rating and the circuit current before making any connections.

DC Voltmeter

The voltmeter is used to measure the difference in potential or voltage drop between two points. The voltmeter is connected in parallel to the operating unit. (See figure 34.)

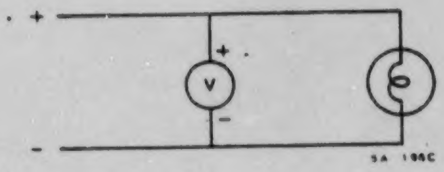


Figure 34. Voltmeter Connected Parallel to the Unit

As you can see from figure 34, the voltmeter is the only unit in a path of current flow. To protect the coil of the meter movement a resistance must be connected in series to it. (See figure 35.)

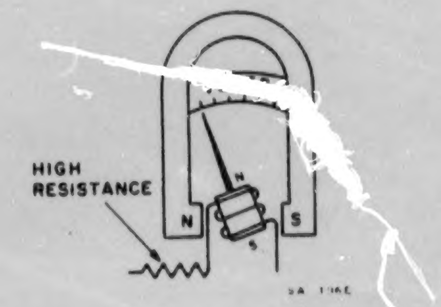


Figure 35. Voltmeter Meter Movement

The purpose of this resistance is to limit the current flow through the meter movement. Since the resistance of the meter is fixed, the amount of voltage applied to the terminals determines the amount of current flow through the coil, thereby determining the pointer movement.

Remember:

A voltmeter is connected parallel with the unit.

Connect the positive terminal of the voltmeter toward the positive side of the circuit as shown in figure 35.

The range of voltage you are checking.

Ohmmeter

An ohmmeter is used to measure resistance. It contains a battery and a rheostat in series with the coil. (See figure 36.)

The battery supplies the power to operate the meter movement. Therefore, the main power source must be disconnected when using the meter. Severe damage to the meter can occur if this precaution is disregarded.

When ohmmeter terminals are not connected to a conductor, the circuit is open, consequently since there is no connection from the negative side of the battery to the positive side of the battery, the coil cannot be energized, and the pointer rests at infinity. Infinity means that the resistance is too great to be measured. Infinity is represented by the symbol ∞ shown in figure 37.

When the terminals are connected to a resistor, the circuit through the coil is completed. The pointer moves to indicate the correct resistance. If the terminals were connected across a fuse or switch, for example, the resistance would be too small to measure. The ohmmeter should indicate zero resistance. Note in figure 37 that zero is at the opposite end of the scale from infinite resistance.

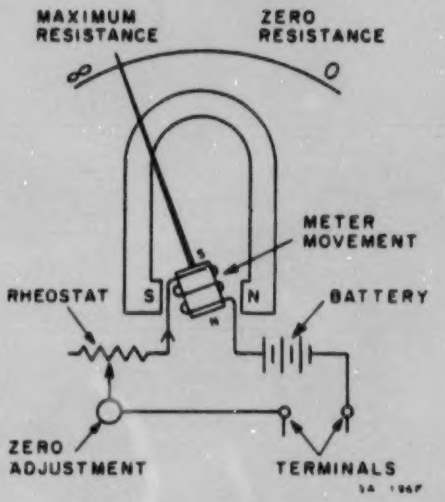

MAXIMUM RESISTANCE
ZERO RESISTANCE
∞
0
METER MOVEMENT
RHEOSTAT
S
N
BATTERY
ZERO ADJUSTMENT
TERMINALS
SA 106F

Figure 36. Ohmmeter

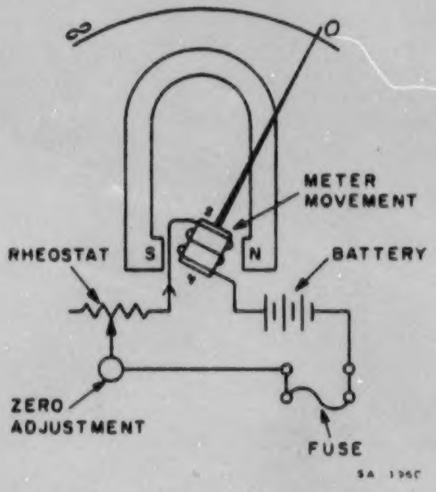

∞
0
METER MOVEMENT
RHEOSTAT
S
N
BATTERY
ZERO ADJUSTMENT
FUSE
SA 106C

Figure 37. Ohmmeter Indicates Zero Resistance Across Fuse

The current output capacity of a battery may decrease with age or abuse. A rheostat in the circuit compensates for the change. Turning a "zero adjusting" knob varies the resistance, thereby allowing more or less current to flow through the coil.

To adjust the pointer to zero before measuring resistance, the ohmmeter leads are touched together to allow the pointer to move to zero. If it does not, the leads should be held together while the zero adjusting knob is rotated until pointer does move to zero.

Remember:

> The ohmmeter has its own source of power. Circuit power must be OFF.
>
> Adjust the pointer to zero before using the meter. Use the proper range jack for accurate reading.

Multimeter, TS-297/U

The multimeter, TS-297/U, is a meter for measuring ac and dc voltages, direct current, and resistance. To select the desired meter, a SWITCH KNOB is set on OHMS, ACV, DCV, or MA. (See figure 38.)

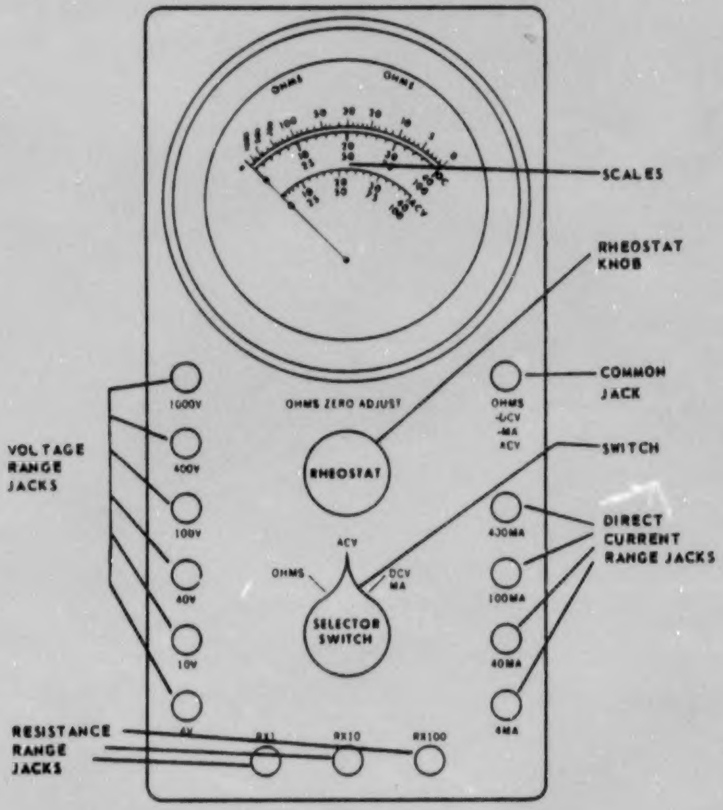

OHMS
OHMS
SCALES
RHEOSTAT KNOB
COMMON JACK
SWITCH
DIRECT CURRENT RANGE JACKS
VOLTAGE RANGE JACKS
1000V
400V
100V
40V
10V
4V
OHMS ZERO ADJUST
RHEOSTAT
OHMS -DCV -MA ACV
ACV
OHMS
DCV MA
SELECTOR SWITCH
400MA
100MA
40MA
4MA
RESISTANCE RANGE JACKS
RX1
RX10
RX100

Figure 38. Multimeter TS-297/U

The multimeter has a black and a red lead. The black lead is always placed in the common jack. (See figure 38 to locate this jack.) The red lead is placed in the jack according to the function desired. The 4V through 1000V jacks are for ac or dc voltage measurements. For example, if you wanted to measure a 28V dc power source, the switch knob would be placed on DCV, the black lead placed in the common jack and the red lead placed in 40V.

The R X 1, R X 10, and R X 100 jacks are used for measuring resistance and the 4 MA to 400 MA jacks are used for measuring direct current.

The dial is marked with three scales as shown in figure 39. The scale to be read depends on the switch knob setting and the range jack into which the red lead is placed. The top scale is used for measuring resistance. It ranges from 0 to ∞.

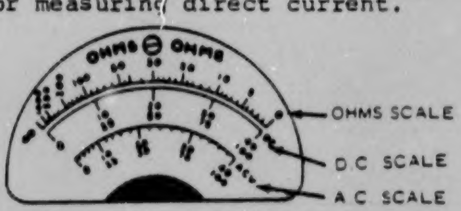


Figure 39. Three Scales on Dial

The center scales are used for dc voltage measurements and dc milliamperes. The scale ending in 40 is used when the red lead is in a range jack beginning with "4." The scale ending in 100 is used when the red lead is placed in a range jack beginning with "1." (See figures 38 and 39.)

The lower scale, labeled ac is used for measuring ac voltage. It also has two sets of calibrations - zero to 40 and zero to 100, used in the same way as the dc.

The RHEOSTAT KNOB is used to adjust the meter pointer to zero when the multimeter is used as an ohmmeter.

Remember:

> To prevent damage to the multimeter when measuring voltage, current, or resistance, always start with the highest range to obtain the approximate reading. Then use the lowest range possible as indicated by the reading.
>
> Be sure to read the correct scale.
>
> High voltages are dangerous and may be fatal. Follow posted safety rules.
>
> Shut off power when measuring resistance.
>
> Isolate components for accuracy.
>
> DO NOT LEAVE THE SWITCH ON OHMS WHEN THE MULTIMETER IS NOT IN USE, BECAUSE ACCIDENTAL SHORTING OF THE TEST PRODS WILL TEND TO DISCHARGE THE BATTERY.

SUMMARY

Magnetism means the ability to attract iron. Hard steel is used in making permanent magnets and soft iron is used in making temporary magnets. All magnets have a north and south pole and a magnetic field surrounds the magnet.

Electromagnets are made by inserting a soft iron core within an energized coil of a conductor.

Permanent and electromagnets are used in meter movements. Meters used by the refrigeration specialist are the dc and ac voltmeters, the ammeter, and the ohmmeter.

Polarity must be observed when connecting ammeters and voltmeters in a circuit. Power must be OFF when connecting an ohmmeter in a circuit.

The multimeter can be used as an ohmmeter, an ammeter, and a voltmeter.

QUESTIONS

1. List three things that determine the strength of an electromagnet.
2. What does the symbol ∞ mean?
3. Which meter has its own source of power?
4. What does any dc basic meter movement consist of?
5. What is an electromagnet?
6. How can the polarity of an electromagnet be determined?
7. What is the area of attraction around the magnet called?

SECTION III

OHM'S LAW AND CIRCUITS

INTRODUCTION

Your ability to analyze electrical troubles will depend upon your knowledge of the circuits involved. This section of the study guide explains the types of circuits, their characteristics, and the relationship between voltage, current, and resistance in each type of circuit.

OHM'S LAW

There is a definite relationship between current, voltage and resistance of any circuit. If the voltage is increased, the current increases proportionately. If the resistance is increased, the current decreases proportionately. This relationship is known as Ohm's law. Ohm's law can be stated as follows: The current in a circuit is equal to the voltage divided by the resistance. Mathematically it is written as follows:

$$I = \frac{E}{R}$$

The letter I stands for current; E stands for voltage or EMF; R stands for resistance. When voltage is known to be 12V and resistance is known to be 4 Ω, these known values are substituted for their corresponding letters in the formula. The formula now reads

$$I = \frac{12V}{4\Omega}$$

Current may then be found by dividing. I will equal 3 amperes

The equation can be converted to read $R = \frac{E}{I}$. Let us suppose that the known factors are 12 volts and 3 amperes. The known values are again substituted in the formula.

$$R = \frac{12V}{3A}.$$

By dividing we find the resistance to be 4 Ω

Still another equation is available, $E = IR$. Suppose that the known factors are 3 amperes of current and 4 Ω of resistance. After substitution, the formula is $E = 3A \times 4\Omega$. By multiplying in this instance, voltage is found to be 12 volts.

These three equations will enable you to find any of three factors (voltage, current, or resistance) if you know the other two. An easy way to remember the three relationships is to place them in a triangle as shown in figure 40.

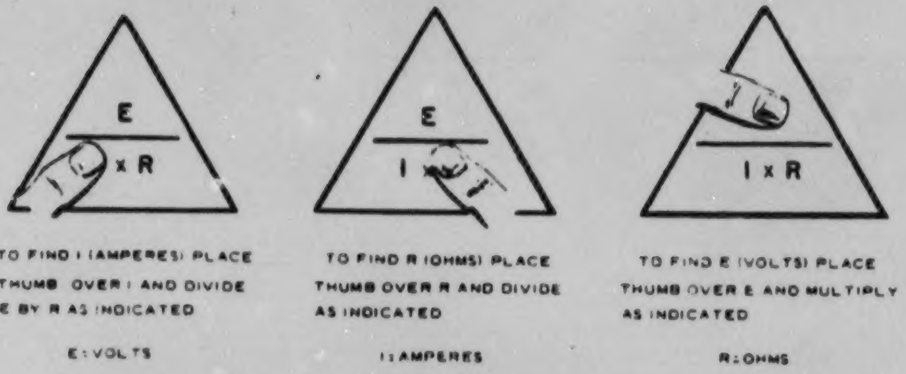

E
I x R
E
I x R
E
I x R
TO FIND I (AMPERES) PLACE THUMB OVER I AND DIVIDE E BY R AS INDICATED
TO FIND R (OHMS) PLACE THUMB OVER R AND DIVIDE AS INDICATED
TO FIND E (VOLTS) PLACE THUMB OVER E AND MULTIPLY AS INDICATED
E: VOLTS
I: AMPERES
R: OHMS

Figure 40. Ohm's Law Chart

If you place your finger over the factor you do not know, the relative positions of the other two known factors will tell you what to do.

TYPES OF CIRCUITS

Electrical circuits can be divided into three general classifications: series, parallel, and series-parallel.

Series Circuits

A series circuit can be defined as one in which there is only one path through which the voltage can force the current. In figure 41 is a diagram of a series circuit.

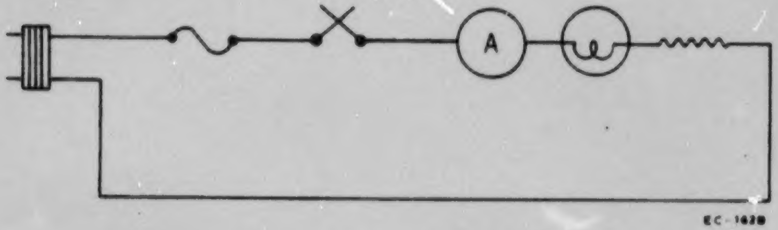


Figure 41. A Series Circuit

CHARACTERISTICS OF SERIES CIRCUITS. Since there is but one path for the current, all the current is forced through each resistance; consequently, current is the same throughout the circuit. In figure 42, the ammeter has been wired between the 6 Ω lamp and the 2 Ω resistor. The EMF is 24V. The ammeter is indicating 3 amperes of current.

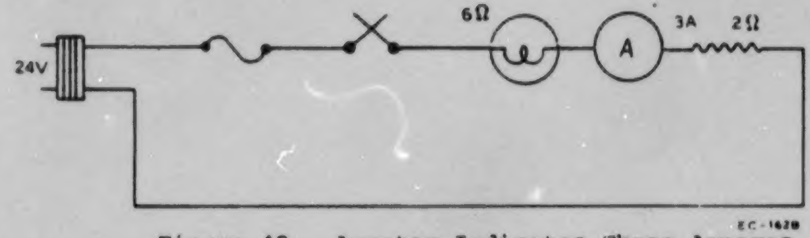

24V
6Ω
A
3A
2Ω
EC-1628

Figure 42. Ammeter Indicates Three Amperes

In figure 43, the resistance and EMF have remained the same. You will note that the ammeter has been wired so that it is now between the lamp and the switch. Since resistance and voltage determine current flow and these have remained constant, the ammeter still indicates 3 amperes.

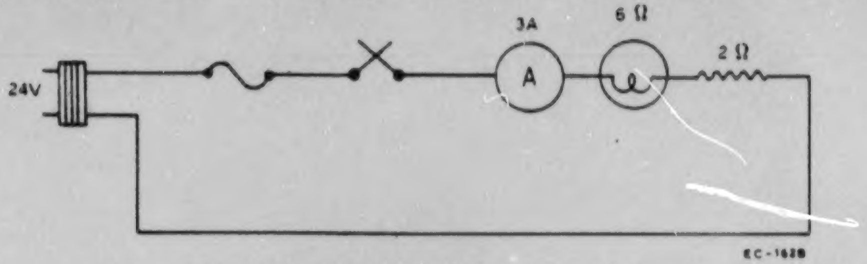


Figure 43. Ammeter Continues to Indicate Three Amperes

The second characteristic of a series circuit is that the sum of the voltage drops across each of the resistances should equal the total or applied voltage. (See figure 44.)

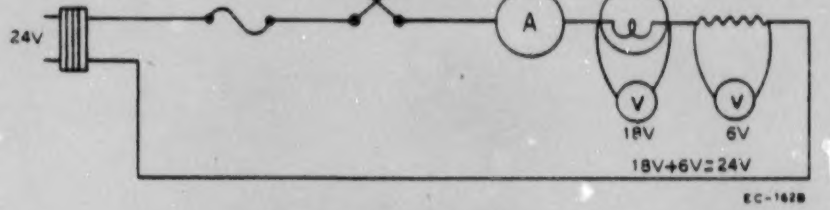


Figure 44. Adding Voltage Drops

The third characteristic is that the total resistance is equal to the sum of the resistances of each unit. (See figure 45.)

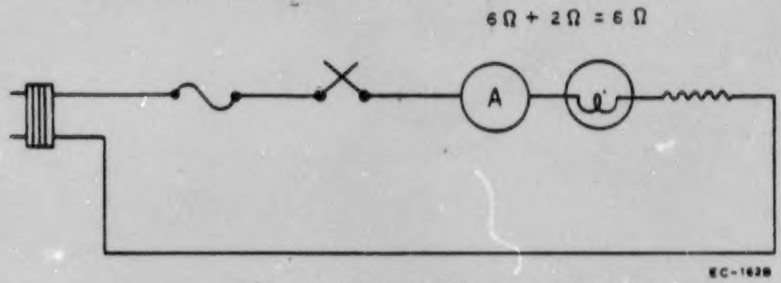


Figure 45. Adding Resistances

Parallel Circuits

A parallel circuit is one in which there are two or more paths for voltage to force current through, containing only one unit of resistance in a path. (See figure 46.)

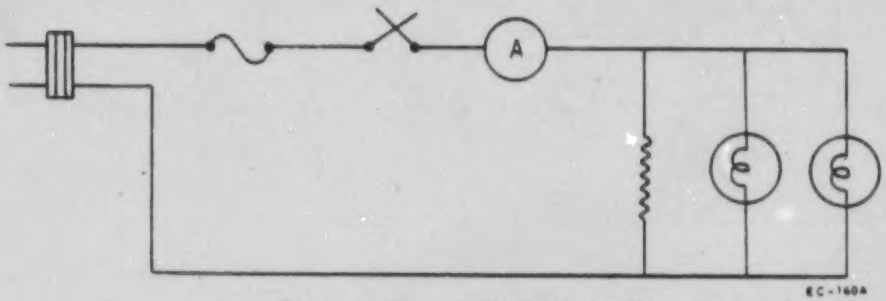


Figure 46. A Parallel Circuit

CHARACTERISTICS OF PARALLEL CIRCUITS. The total current in the circuit is equal to the sum of the currents flowing through all the paths. (See figure 47.)

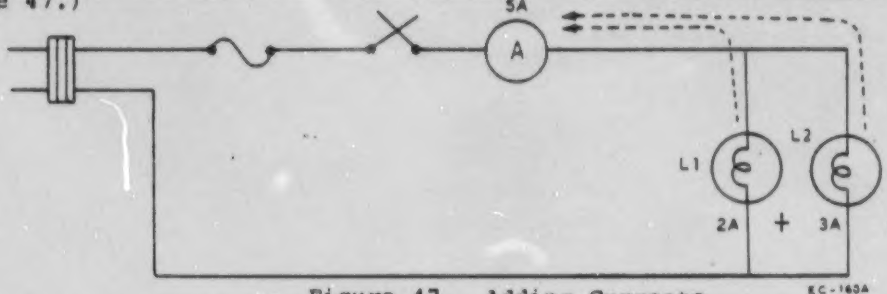


Figure 47. Adding Currents

From figure 47, you can see that the total amount of current is greater than the current in any individual path.

The second characteristic is that the voltage across each unit in parallel is the same. (See figure 48.)

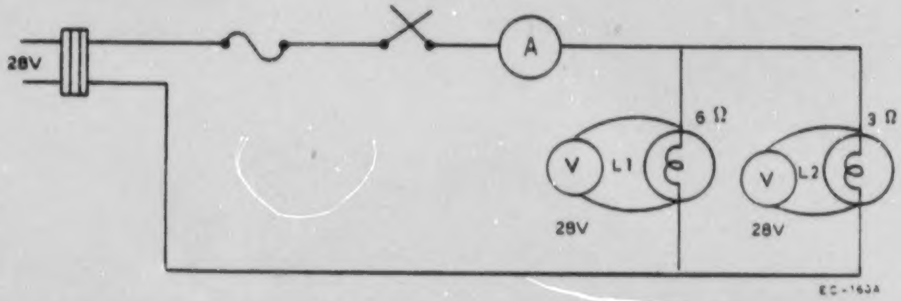


Figure 48. Voltage Drops the Same

The total resistance, that is, the resistance of the circuit as a whole, is less than the smallest resistance in it. By referring to figure 48, note that the resistance of L_1 is 6 Ω and the resistance of L_2 is 3 Ω. The total resistance of the circuit must be less than 3 Ω.

Series-Parallel Circuits

A series-parallel circuit is one in which some units are in series and others are in parallel. A diagram of a series-parallel circuit can be seen in figure 49.

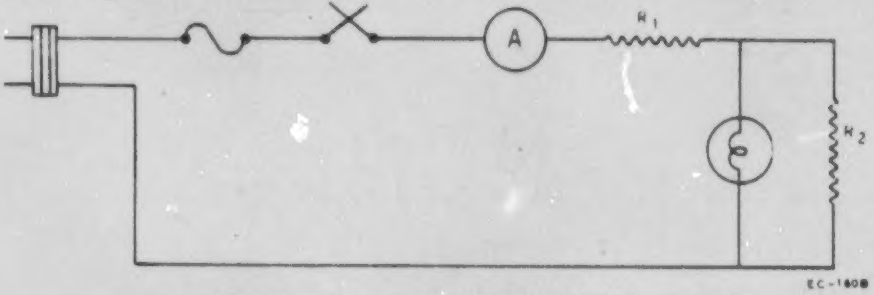


Figure 49. A Series-Parallel Circuit

From figure 49, you can see that the two resistors are in series and R_1 and the light are in series, but that R_2 and the light are in parallel.

CHARACTERISTICS OF SERIES-PARALLEL CIRCUITS. The characteristics for the series-parallel circuit are a combination of those for the series and the circuits. Study figure 50.

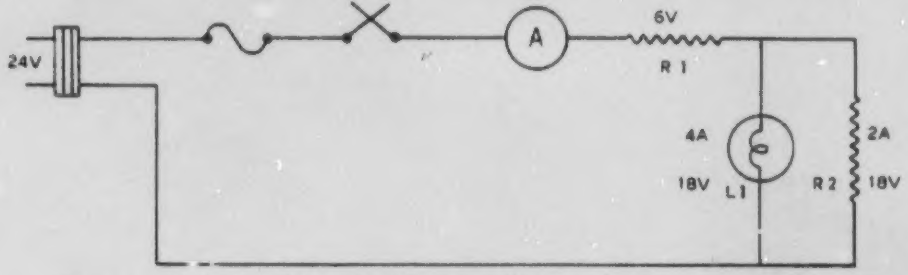


Figure 50. Voltage and Current in a Series-Parallel Circuit

SUMMARY

The relationship between voltage, current, and resistance is called Ohm's law. To use the Ohm's law triangle two factors must be known.

There are three types of circuits; series, parallel, and series-parallel.

Each type of circuit has specific characteristics concerning voltage, current, and resistance.

In a series circuit current is the same, voltage drops can be added, and resistances can be added.

In a parallel circuit, only the currents can be added. Voltage drops are the same and total resistance is less than the smallest resistance.

QUESTIONS

1. What is the definition of a series circuit?
2. How can Ohm's law be used to find current?
3. What is the Characteristics of Voltage in a series circuit?
4. How can total current be determined in a parallel circuit?
5. In which type of circuit can the voltage drops be added?
6. What does the letter I stand for in Ohm's law?

SECTION IV

TROUBLESHOOTING DC CIRCUITS

INTRODUCTION

Trouble with a refrigeration unit often involves electrical problems. The refrigeration specialist should be able to troubleshoot electrical circuits. He can simplify his problem by determining if the malfunction is electrical or mechanical. Troubleshooting can be defined as a "systematic method of locating faults in an electrical circuit."

WIRING DIAGRAMS

A wiring diagram of the electrical system on which you are working should be obtained so that you will understand the type of circuits and the units involved. In figure 51, a wiring diagram of two circuits is shown. By studying them, you can see that circuit A consists of a fuse, switch, conductors, and two lights wired parallel to each other. Circuit B consists of the same units. A picture of the circuit will aid in troubleshooting and making operational checks of the units.

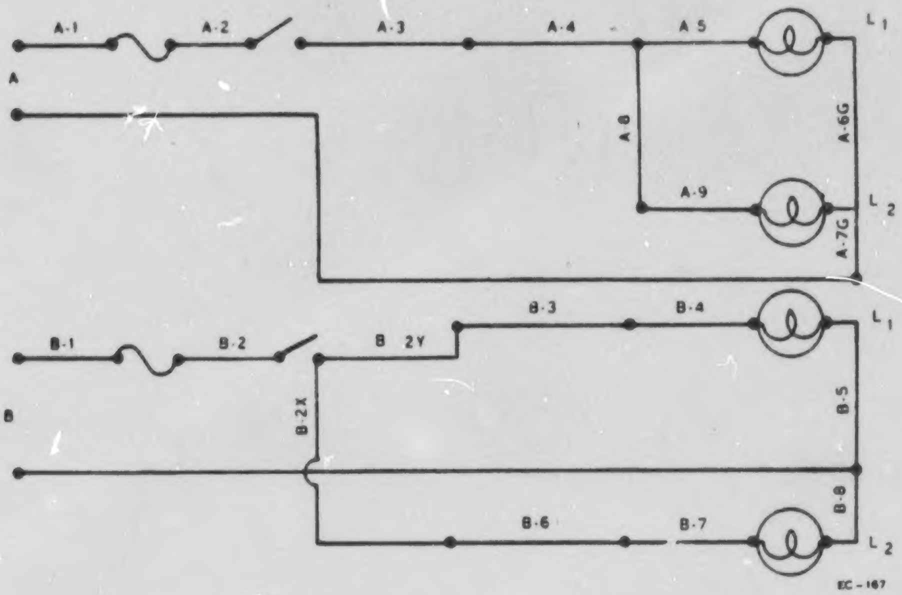


Figure 51. A Wiring Diagram

OPERATIONAL CHECK

After studying the diagram, check the circuit for normal operation. An operational check of circuit A, figure 51, would be performed by closing the switch and checking to see whether both lights burn. If they do not burn, or if they should be burning with switch A in the OFF position, then the circuit is considered faulty.

TYPES OF TROUBLES

An important fact to remember is that there are only three types of troubles; opens, shorts, and low power.

Opens

An open circuit is one that has a break somewhere in it. This break could be located in the wire, in the switch, fuse, or in the unit of resistance. In fact, it could exist anywhere. Naturally, if there is a break, there can be no current flow; consequently, the unit of resistance would not be operating. (See figure 52.)

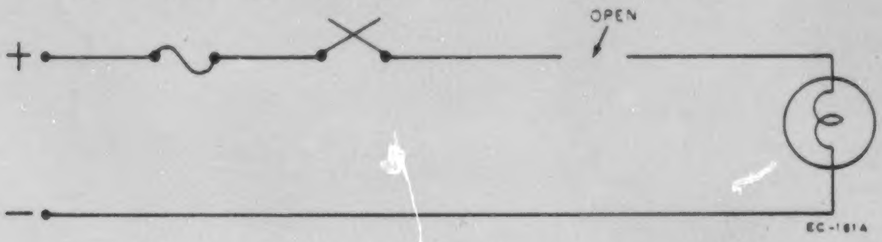


Figure 52. Open Wire

There are four different testers that can be used to find an open. These are the voltmeter, continuity tester, ohmmeter, and test light.

LOCATING OPENS. The exact location of an open can be found by using the voltmeter. You should, first of all, understand what a voltmeter indicates in a normal operating circuit. Figure 53 illustrates normal voltmeter readings throughout the circuit.

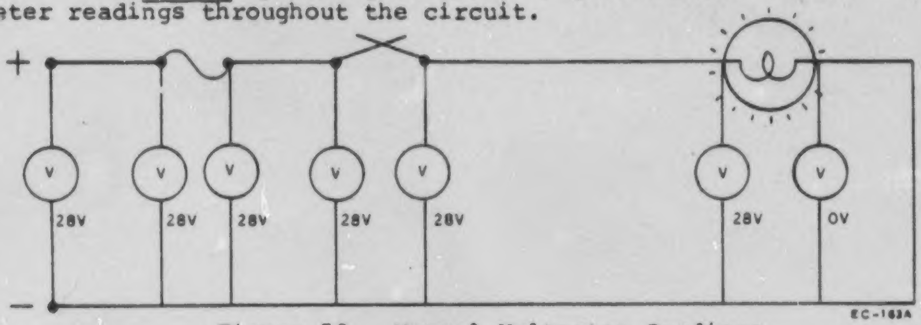


Figure 53. Normal Voltmeter Readings

A voltmeter connected positive to negative should always indicate the difference in voltage across the two points. A voltmeter connected negative-to-negative or positive-to-positive should not give a difference in electrical pressure. (See figure 53.) Readings other than these are considered abnormal. Exact location of an open can be found in the positive or negative parts of the circuit between a normal and an abnormal reading.

Figure 54 illustrates a voltmeter being used to find an open in wire A-4. Note that wire A-4 is in the positive part of the circuit.

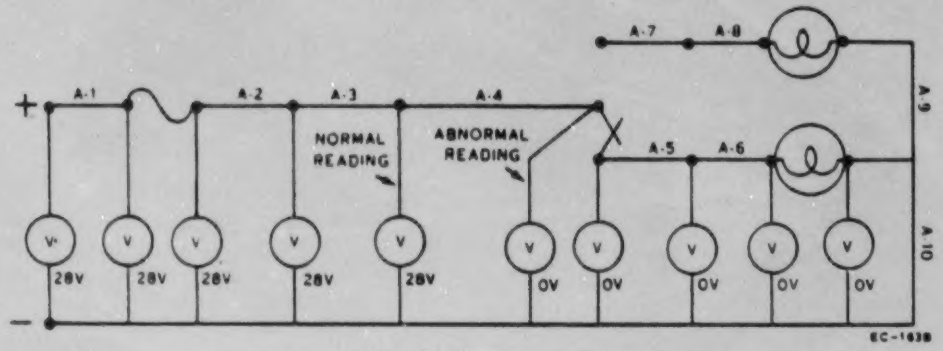

A-7
A-8
+
A-1
A-2
A-3
A-4
A-9
NORMAL READING
ABNORMAL READING
A-5
A-6
V
28V
28V
28V
28V
28V
0V
0V
0V
0V
0V
A-10
−
EC-163B

Figure 54. Locating an Open in Wire A-4

In figure 55, a voltmeter is being used to locate an open in the negative part of the circuit. The exact location is wire A-6.

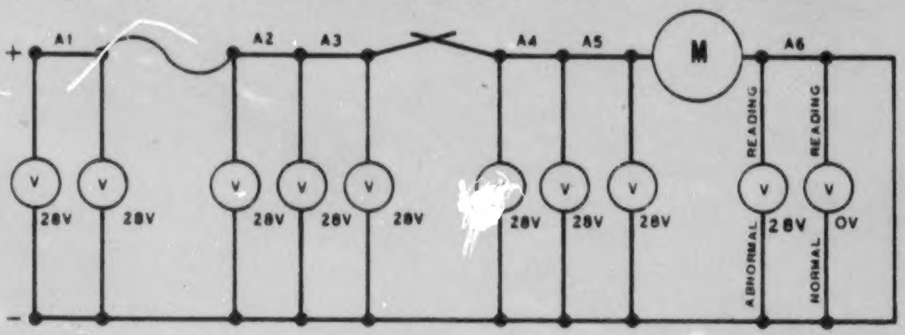

+
A1
A2
A3
A4
A5
M
A6
READING
READING
V
28V
28V
28V
28V
28V
28V
28V
28V
28V
0V
ABNORMAL
NORMAL
−

Figure 55. Locating an Open in Wire A-6

The same procedure is used in troubleshooting an open with a test light; however, a test light will not give an indication of the amount of voltage present. All you know is that there was enough current available to burn the light.

Opens can also be found by using an ohmmeter or a continuity meter. Power must be off and the circuit isolated when using continuity testers. In figure 56 an ohmmeter is being used to locate an open in wire A-6.

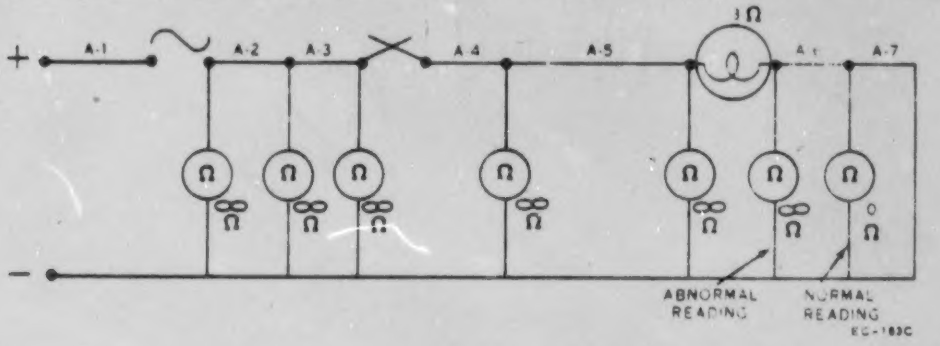

3 Ω
+
A-1
A-2
A-3
A-4
A-5
A-6
A-7
Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
0 Ω
−
ABNORMAL READING
NORMAL READING
EC-163C

Figure 56. Locating an Open with an Ohmmeter

In figure 56 you will notice that the ohmmeter should have been registering continuity all the way through the circuit; the open is found between the continuity reading (0 Ω) and ∞ Ω.

SHORTS

A short means that there is contact where there should not be contact; consequently there is current flow where there should not be current flow. Indications of shorts are units operating that should not be operating, blown fuses, and tripped circuit breakers.

Direct Short

In the case of a direct short, a negative lead is in contact with a positive lead, by passing the unit of resistance.

From figure 57, you can see that current in this situation will take the path of least resistance. The excessive current flow will cause the fuse to blow, or if the protective device happens to be a circuit breaker, the circuit breaker will trip, opening the circuit.

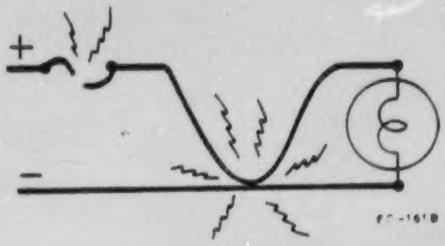


Figure 57. Direct Short

LOCATING DIRECT SHORTS. Some kind of a continuity tester, such as the ohmmeter, continuity meter, or continuity light, should be used in locating direct shorts. The positive leads should be isolated and the testing device connected across the isolated leads. Notice in figure 58, an ohmmeter is being used to locate contact between isolated positive leads and the negative lead. Only the ohmmeter connected to A-4 lead indicates continuity (0 Ω); therefore, A-4 lead is shorted to the negative side of the circuit providing a short cut for current flow.

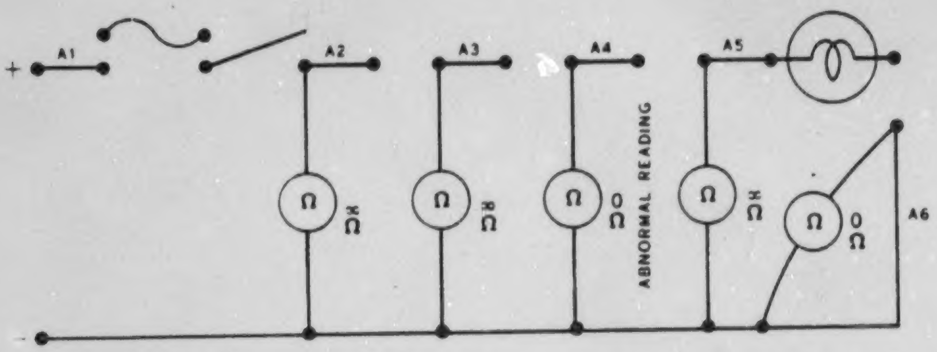


Figure 58. Locating a Direct Short

Cross Shorts

Whereas the direct short is contact between the positive lead of a circuit and the negative lead of a circuit, the cross short is caused by the positive leads of independent circuits coming in contact with each other.

During an operational check a cross short is indicated by two independent units operating from the same switch. In figure 59, positive lead A-8 is touching positive lead A-3. Even though the switch which controls L_2 is open, there is a complete path for current flow from A-3 to A-8; consequently, L_2 burns.

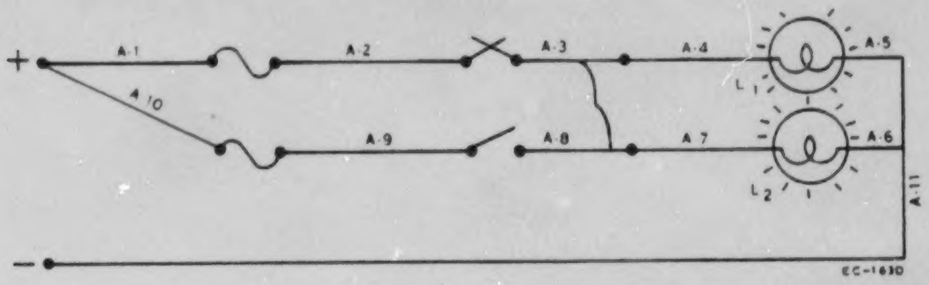


Figure 59. Cross Short

LOCATING CROSS SHORTS. The same testing devices and procedures are used in locating cross shorts as were used in locating direct shorts. Power must be off and the positive leads of both circuits isolated. (See figure 60.)

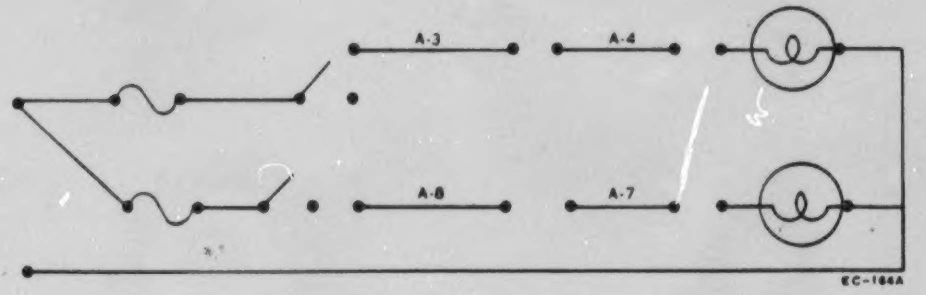


Figure 60. Probable Leads Isolated

After both circuits are isolated, the testing device is connected across the probable leads, such as A-3 to A-7, A-3 to A-8, A-4 to A-8, or A-4 to A-7. Note that any of these combinations would have the same effect. In figure 61, the ohmmeter shows the cross short to between A-3 and A-8.

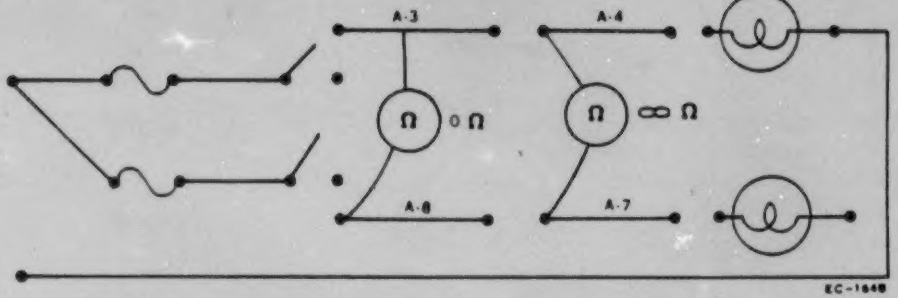


Figure 61. Locating a Cross Short

A shorted switch is one that fails to break contact when it is placed in the off position. The effect of a shorted switch is that the unit operates continuously. Any testing device can be used to determine whether the switch is defective. In figure 62, an ohmmeter indicates the switch is shorted.

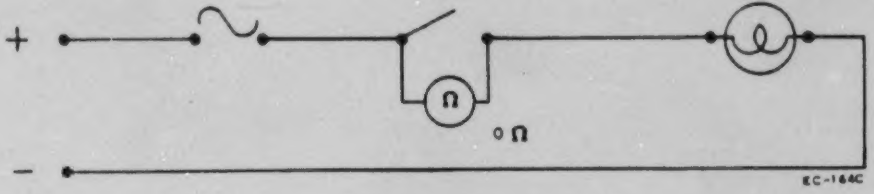


Figure 62. Checking for a Shorted Switch

Low Power

This condition is often found in old buildings or in areas where the electrical load has been increased without increasing the size or number of electrical circuits. A low power condition is indicated by sluggish operation of units and dim lights.

If a low power condition is suspected, all the electrical units on the circuit should be turned on. This should create maximum current flow. Voltage drops across the units should be compared with total voltage. Figure 63 shows a line loss check.

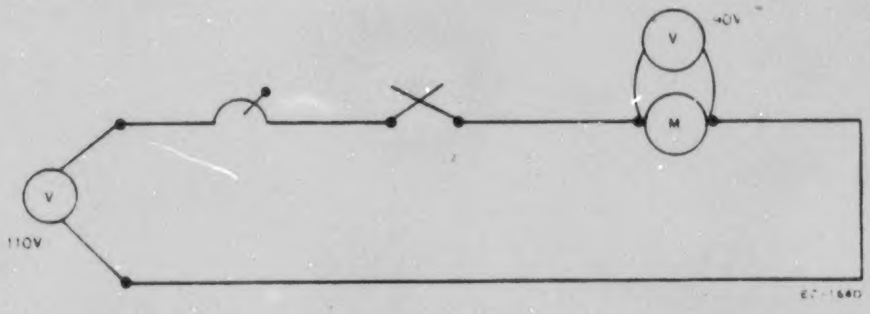


Figure 63. Voltage Drops Should Equal Total Voltage

If a low power condition is discovered, the electrical load must be reduced or a new circuit installed.

SUMMARY

Troubleshooting is a systematic means of locating malfunctions in a circuit.

The three types of troubles are: opens, shorts, and low power.

Opens prevent the flow of current, whereas a short allows it to flow where it is not wanted. Low power causes sluggish operation of units.

The testing devices are the voltmeter, continuity meter, ohmmeter, continuity light, and test light.

Continuity devices must be used in circuits where the power is off and the circuit isolated. Voltmeter and test light are used in circuits where the power is left on.

QUESTIONS

1. What testing device cannot be used in locating a cross short?
2. What is the indication of a direct short?
3. What is one cause of low power?
4. What testing devices are used in circuits where power can be left on?
5. How is the circuit checked for low power?
6. What is the effect of an open circuit?
7. What is a shorted switch?

REFERENCES

1. Modern Refrigeration and Air Conditioning, Althouse and Turnquist.
2. Commercial and Industrial Refrigeration, Nelson

WORKBOOK 3ABR54530-II-1-P1 thru P5

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

ELECTRICAL PRINCIPLES AND DIRECT CURRENT CIRCUITS

April 1975

SHEPPARD AIR FORCE BASE

11-6

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The STUDY GUIDE (SG) presents the information you need to complete the unit of instruction, or makes assignments for you to read in other publications which contain the required information.

The WORKBOOK (WB) contains work procedures designed to help you achieve the learning objectives of the unit of instruction. Knowledge acquired from using the study guide will help you perform the missions or exercises, solve the problems, or answer questions presented in the workbook.

The STUDY GUIDE AND WORKBOOK (SW) contains both SG and WB material under one cover. The two training publications are combined when the WB is not designed for you to write in, or when both SG and WB are issued for you to keep.

The PROGRAMMED TEXT (PT) presents information in planned steps with provisions for you to actively respond to each step. You are given immediate knowledge of the correctness of each response. PTs may either replace or augment SGs and WBs.

The HANDOUT (HO) contains supplementary training materials in the form of flow charts, block diagrams, printouts, case problems, tables, forms, charts, and similar materials.

Training publications are designed for ATC course use only. They are updated as necessary for training purposes, but are NOT to be used on the job as authoritative references in preference to Technical Orders or other official publications.

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Copies of superseded publication may be used until stock is exhausted.

WB 3ABR54530-II-1-P1
April 1975

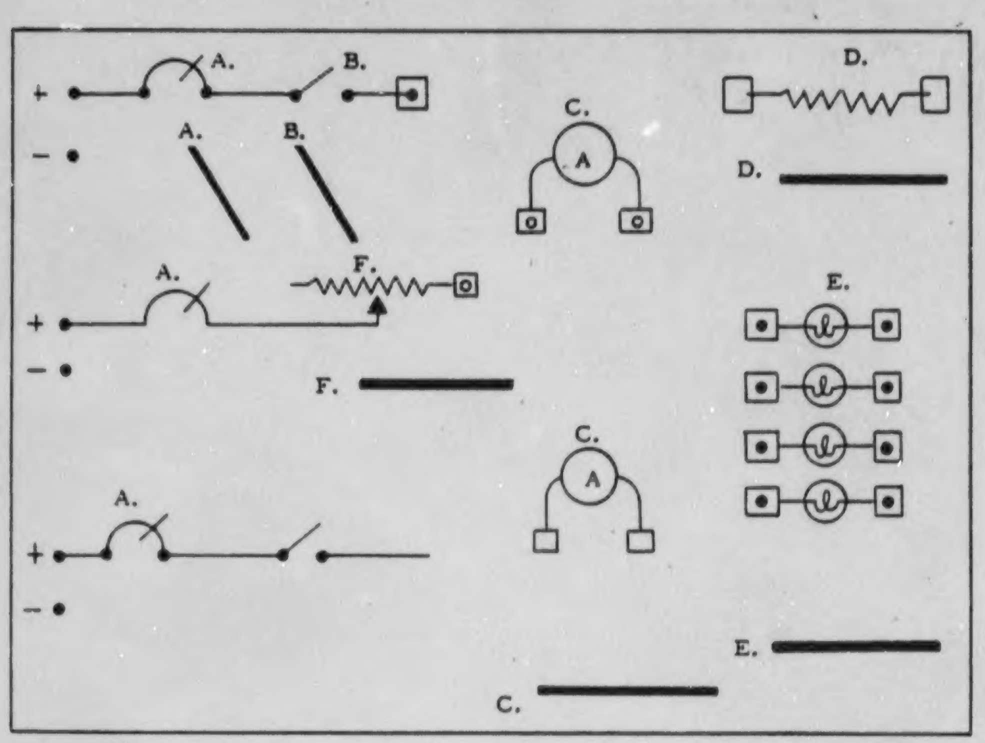
IDENTIFY ELECTRICAL UNITS AND CIRCUITS

OBJECTIVES

To aid you in gaining practical experience in identifying electrical symbols, using electrical diagrams, wiring electrical circuits, and checking current flow in circuits.

PART I

IDENTIFICATION OF UNITS ON THE TRAINER



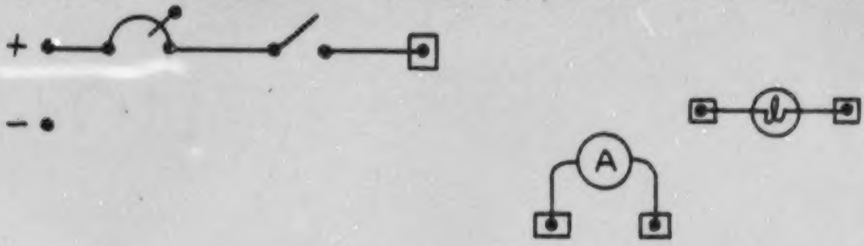
A Diagram of the Trainer

1. Above is a diagram of the trainer to which you have been assigned. Under each unit on the diagram is a space provided to write the name of the unit. Identify each unit by writing its nomenclature on the heavy black line.

PART II

AN ELECTRICAL DIAGRAM

1. Before wiring any electrical circuit, a diagram of the circuit should be drawn. The units to be included in the diagram are a circuit breaker, a SPST switch, an ammeter, and a light. Draw lines on the following diagram to represent the wires you will place on the trainer.



2. Have the instructor check your diagram.

PART III

WIRING AND OPERATION OF THE CIRCUITS

CAUTION: Remove all jewelry.

1. Wire the circuits on the trainer assigned to you by the instructor. Use your diagram as a guide.

   NOTE: Use the larger bulb.

2. Have the instructor check your wiring.

3. Turn the circuit breaker and the switch to the ON position.

   a. How much current is in the circuit? ________________________

   b. What meter is used to measure current? ____________________

   c. What is the unit of measure for current? ________________

   d. What is current? ____

4. Turn the switch OFF.

5. Replace the bulb with a smaller bulb.

6. Turn the switch ON.

   a. How much current is in the circuit? ________________________

   b. Did current increase, decrease, or remain the same? _______

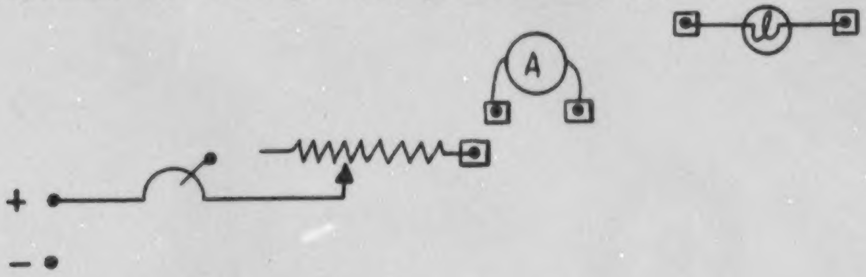
   c. Why? ____

d. What determines the amount of current flow in the circuit?

____

REMOVE ALL WIRES

7. The units to be included in the circuit are a circuit breaker, a rheostat, an ammeter, and a light. Draw lines on the following diagram to represent the wires you will place on the trainer.



8. Have the instructor check your diagram.

9. Wire the circuit on the trainer.

10. Have the instructor check your wiring.

11. Turn the circuit breaker to the ON position.

12. Turn the rheostat as far to the left as you can without turning the light off.

a. How much current is in the circuit? ______________

b. Does the light burn "bright" or "dim"? ______________

13. Turn the rheostat as far to the right as possible without turning the light off.

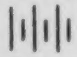
a. How much current is in the circuit? ______________

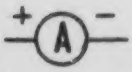
b. Did the current increase, decrease, or remain the same?

____

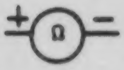
c. Does the light burn bright or dim? ______________

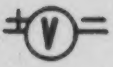
14. Beside each of the following symbols, write its name.

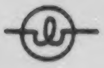
a.  Name ______________

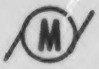
b. 

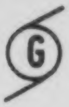
Name ______________

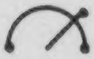
c.  Name ____________________

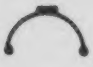
d.  Name ____________________

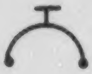
e.  Name ____________________

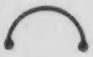
f.  Name ____________________

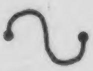
g.  Name ____________________

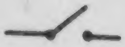
h.  Name ____________________

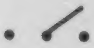
i.  Name ____________________

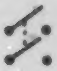
j.  Name ____________________

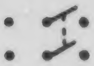
k.  Name ____________________

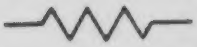
l.  Name ____________________

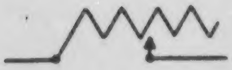
m.  Name ____________________

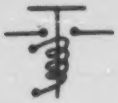
n.  Name ____________________

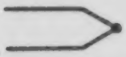
o.  Name ____________________

p.  Name ____________________

q.  Name ____________________

r.  Name ____________________

s.  Name ____________________

t.  Name ____________________

WB 3ABR54530-II-1-P2
April 1975

MULTIMETER READING

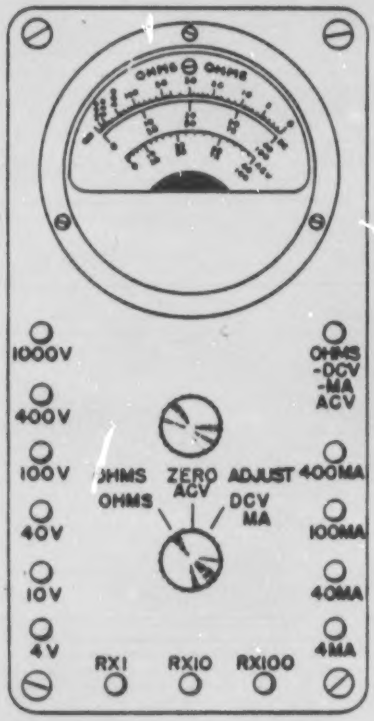
OBJECTIVE

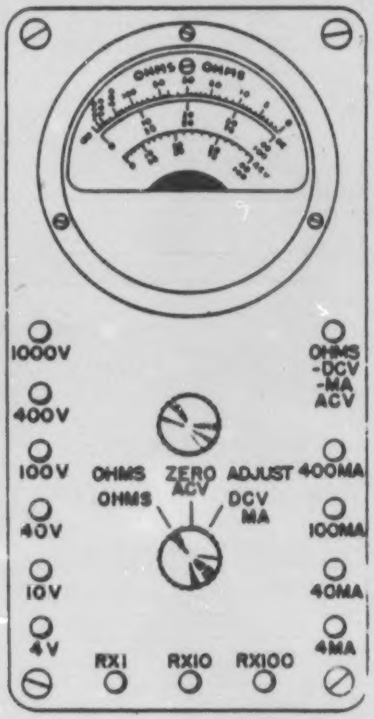
To learn to set the multimeter and measure dc voltage, ac voltage, and resistance.

PART I

USING THE MULTIMETER AS A DC VOLTMETER

1. Draw on the following meter faces, the indicating needle in its proper position. Then fill in the blanks below the meter faces to show the proper setting of switch knob and range jack for the meter indication given.


OHMS
OHMS
1000V
400V
100V
40V
10V
4V
OHMS
OHMS
ZERO
ACV
ADJUST
DCV
MA
OHMS
-DCV
-MA
ACV
400MA
100MA
40MA
4MA
RX1
RX10
RX100

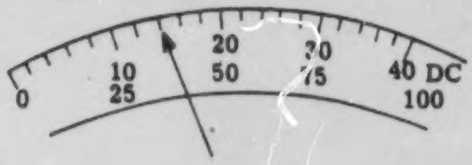

OHMS
OHMS
1000V
400V
100V
40V
10V
4V
OHMS
OHMS
ZERO
ACV
ADJUST
DCV
MA
OHMS
-DCV
-MA
ACV
400MA
100MA
40MA
4MA
RX1
RX10
RX100

Indicating 24 V DC
Switch Knob ________
Range Jack ________

Indicating 1.5 V DC
Switch Knob ________
Range Jack ________

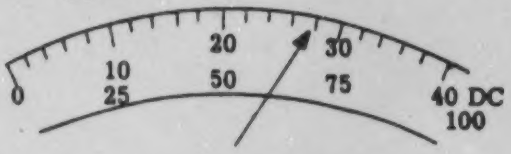
2. In the diagrams below, different range jacks are listed below each meter face. Write what the meter would be indicating on each specific range in the blanks provided.

a.


0
10
25
20
50
30
75
40 DC
100

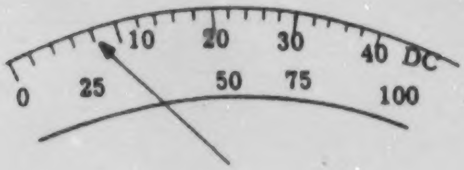
Range Jack	Reading
1000 V	____________ Volts
100 V	____________ Volts
10 V	____________ Volts

b.


0
10
25
20
50
30
75
40 DC
100

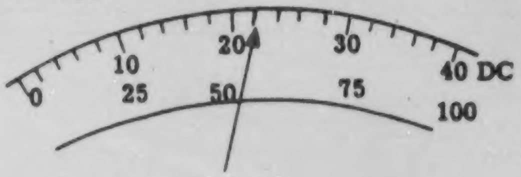
Range Jack	Reading
400 V	______________ Volts
40 V	______________ Volts
4 V	______________ Volts

c.


0
10
25
20
50
30
75
40 DC
100

Range Jack	Reading
100 V	__________ Volts
4 V	__________ Volts
1000 V	__________ Volts
10 V	__________ Volts

d.


0
10
25
20
50
30
75
40 DC
100

Range Jack	Reading
40 V	___________ Volts
100 V	___________ Volts
10 V	___________ Volts
4 V	___________ Volts

3. On the trainer assigned to you by the instructor, put the trainer cord plug in a 110V ac receptacle.

4. Set the trainer switch to DC position.

NOTE: Red light should burn.

5. Set the multimeter to measure dc voltages.

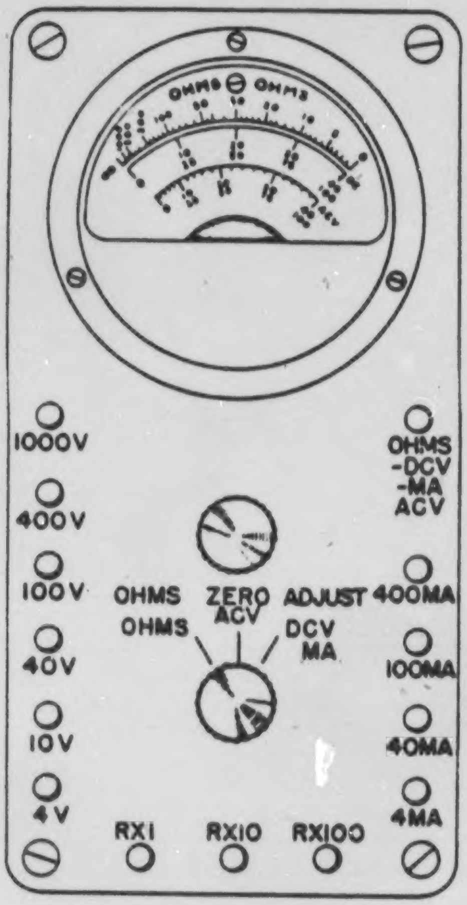
6. Make and record voltage measurements between trainer terminals indicated below.

Trainer Terminals	Voltage
1 to 2	
2 to 17	
3 to 6	
4 to 8	
4 to 17	
5 to 10	
6 to 12	
7 to 14	
10 to 13	
12 to 17	
14 to 16	
14 to 18	
15 to 17	
16 to 17	
17 to 18	

PART II

Using the Multimeter as an A.C. Voltmeter

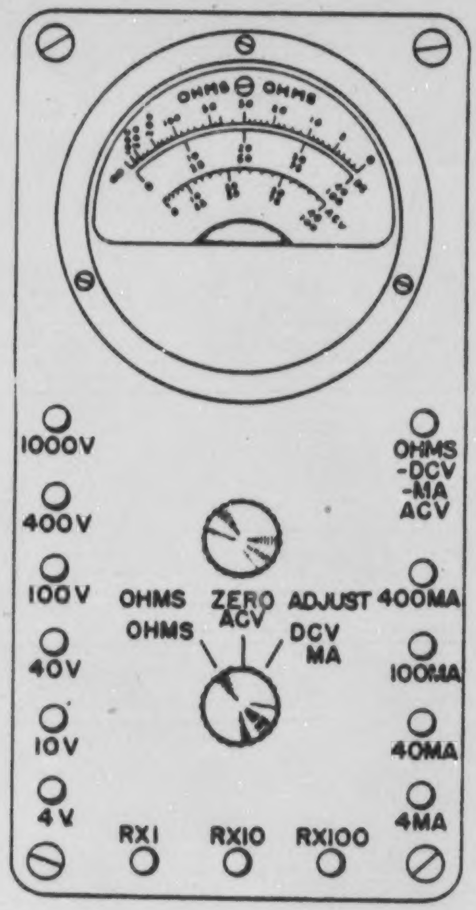
1. Draw on the following meter faces the indicating needle in its proper position. Then fill in the blanks below the meter faces to show the proper setting of switch knob and range jack for the meter indication given.


OHMS
OHMS
1000V
400V
100V
40V
10V
4V
OHMS -DCV -MA ACV
OHMS ZERO ADJUST
OHMS
ACV
DCV MA
400MA
100MA
40MA
4MA
RX1
RX10
RX100

Indicating 110V AC

Switch Knob ____________________

Range Jack ______________________


OHMS
OHMS
1000V
400V
100V
40V
10V
4V
OHMS -DCV -MA ACV
OHMS ZERO ADJUST
OHMS
ACV
DCV MA
400MA
100MA
40MA
4MA
RX1
RX10
RX100

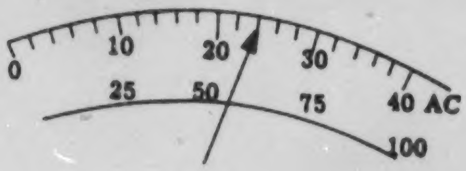
Indicating 220V AC

Switch Knob ____________________

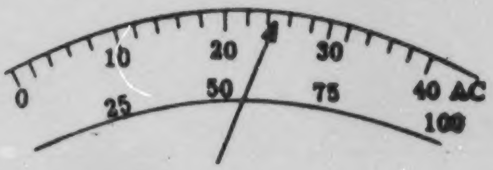
Range Jack ______________________

2. In the diagrams below different range jacks are listed below each meter face. Write what the meter would be indicating on each specific range in the blanks provided.

a.



b.



Range	Reading		Range	Reading	
100 V	______	Volts	4 V	______	Volts
40 V	______	Volts	100 V	______	Volts
10 V	______	Volts	400 V	______	Volts
1000 V	______	Volts	1000 V	______	Volts

3. Set the trainer switch to AC position.

NOTE: Red light does not burn.

4. Set the multimeter to measure ac voltages.

5. Make and record voltage measurements between trainer terminals indicated below.

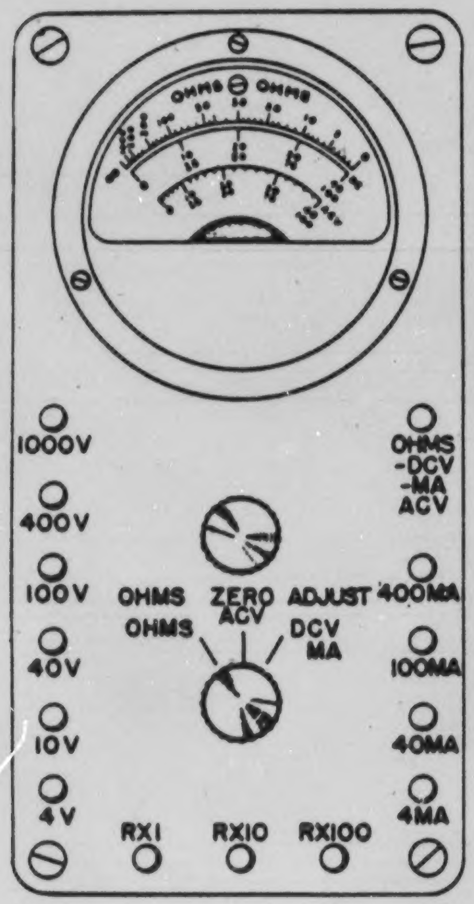
Trainer Terminals	Voltages
2 to 17	______
4 to 17	______
1 to 2	______
3 to 6	______
5 to 10	______
6 to 12	______
7 to 14	______
10 to 13	______
12 to 17	______
14 to 16	______
14 to 18	______
15 to 17	______
16 to 17	______
17 to 18	______

6. Unplug the trainer.

PART III

USING THE MULTIMETER AS AN OHMMETER

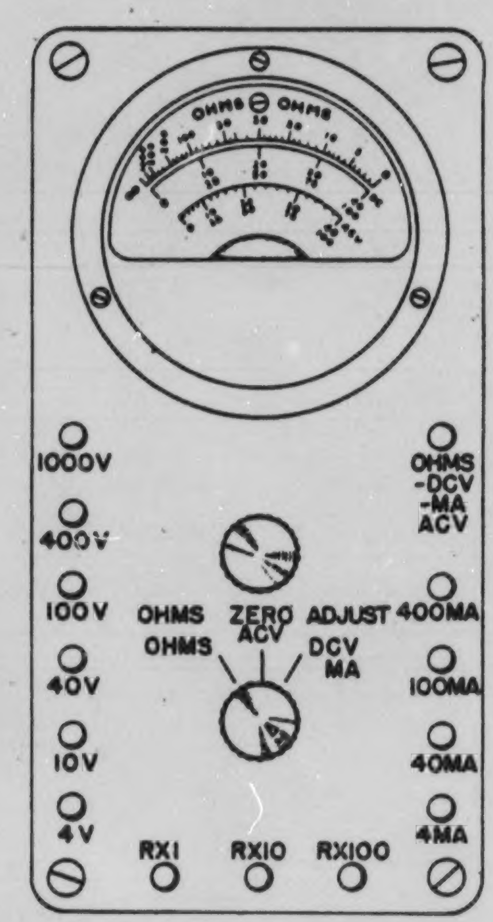
1. Draw on the following meter faces, the indicating needle in its proper position. Then fill in the blanks below the meter faces to show the proper setting of switch knob and range jack for the meter indication given.


OHMS
OHMS
1000V
400V
100V
40V
10V
4V
OHMS
-DCV
-MA
ACV
400MA
100MA
40MA
4MA
OHMS ZERO ADJUST
OHMS
ACV
DCV
MA
RX1
RX10
RX100

Indicating 5 Ohms

Switch Knob ____________

Range Jack ____________


OHMS
OHMS
1000V
400V
100V
40V
10V
4V
OHMS
-DCV
-MA
ACV
400MA
100MA
40MA
4MA
OHMS ZERO ADJUST
OHMS
ACV
DCV
MA
RX1
RX10
RX100

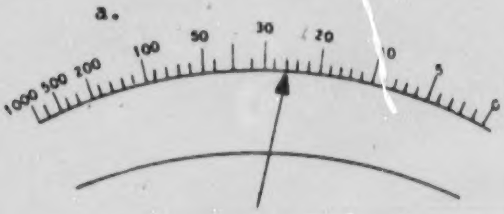
Indicating 2000 Ohms

Switch Knob ____________

Range Jack ____________

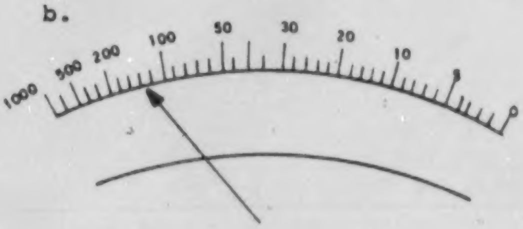
2. In the diagrams below different range jacks are listed below each meter face. Write what the meter would be indicating on each specific range in the blanks provided.

a.



Range	Reading
R x 1	
R x 10	
R x 100	

b.



Range	Reading
R x 1	
R x 10	
R x 100	

3. Set the trainer switch to the OHMS position.

4. Set the multimeter to measure resistance.

5. Make and record measurements between trainer terminals indicated below.

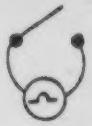
Trainer Terminals	Resistance
1 to 3	
1 to 5	
1 to 11	
2 to 10	
2 to 12	
3 to 13	
4 to 10	
5 to 11	
5 to 13	
7 to 9	
8 to 16	
9 to 17	
10 to 12	
11 to 13	
16 to 18	

PART IV

CHECKING UNITS WITH AN OHMMETER

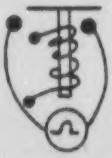
1. In the diagram below, write what the meter indication (∞ for no path I flow, 0 for path for I flow, 0+ for path for I flow with some R in it) would be if the units were good.

a.



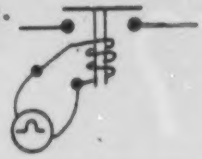
Reading ____

b.



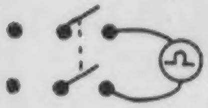
Reading ____

c.



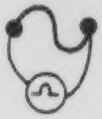
Reading ____

d.



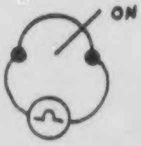
Reading ____

e.



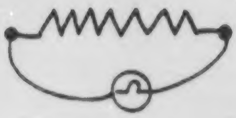
Reading ____

f.



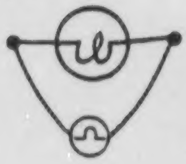
Reading ____

g.



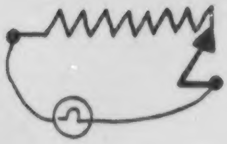
Reading ____

h.



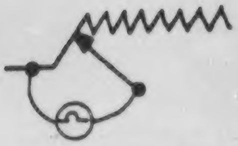
Reading ____

i.



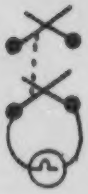
Reading ____

j.



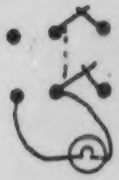
Reading ____

k.



Reading ____

l.



Reading ____

WIRING A SERIES CIRCUIT

OBJECTIVES

To aid you in gaining practical experience in wiring series circuits using electrical diagrams, using Ohm's Law in series circuits, and checking voltage and current in series circuits.

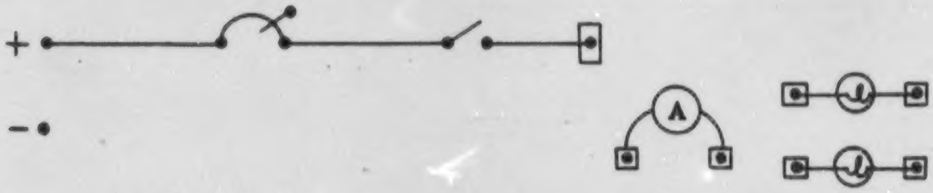
CAUTIONS

Remove jewelry

Turn electrical power OFF before wiring circuits or removing units.

Be sure of correct multimeter setting before making measurements.

1. In the space below, the units to be included in the series circuit are a circuit breaker, an SPST switch, an ammeter, and two lamps. Use lines to represent the wires you will place on the trainer.



2. Have the instructor check your diagram.

3. Wire the circuit on the trainer using your diagram as a guide.

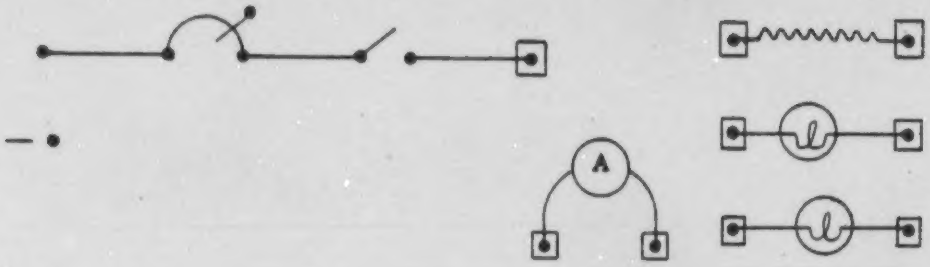
4. Have the instructor check your circuit.

   NOTE: Circuit ammeter will be used to measure current. A multimeter will be used to measure voltage drops and applied voltage. Ohm's law will be used to determine resistance.

5. Turn the switch ON and complete the following for the circuit.

	LAMP 1	LAMP 2	TOTAL
E			
I			
R			

6. In the diagram below, use lines to represent how the fixed resistor would be wired in series to your circuit.



7. Have the instructor check your diagram.

8. Turn the switch ON and complete the following for the circuit.

	LAMP 1	LAMP 2	RESISTOR	TOTAL
E				
I				
R				

9. Remove the wires you placed on the trainer.

10. Complete the following statements.

a. A series circuit is a circuit with _________ path for current flow.

b. The sum of the voltage drops should equal the _____________ voltage.

c. Current is the _____________ throughout a series circuit.

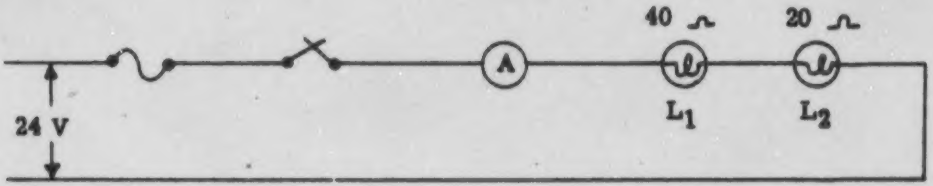
d. Total resistance may be found in a series circuit by _______________ the resistances of all units.

e. As units of resistance are added in a series circuit, will the current flow decrease, increase, or remain the same? ______________

f. As units of resistance are added in a series circuit, will the total resistance decrease, increase, or remain the same? ______________

11. Solve the following circuit problems.

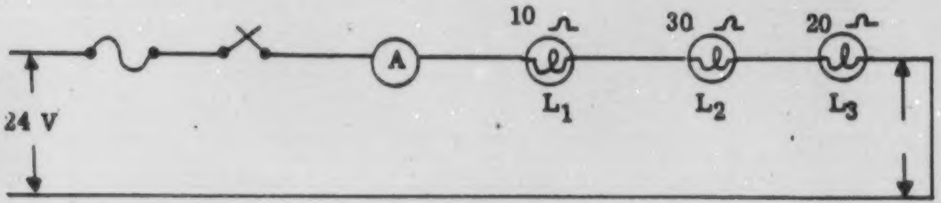
a. Problem No. 1.


40 Ω
20 Ω
A
L$_1$
L$_2$
24 V

Fill in the blanks below

	LAMP 1	LAMP 2	TOTAL
E			
I			
R	40 Ω	20 Ω	

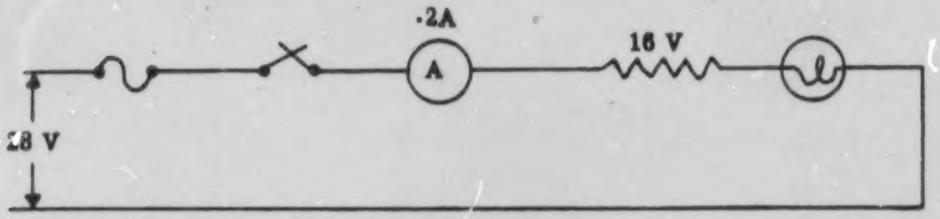
b. Problem No. 2.


10 Ω
30 Ω
20 Ω
A
L$_1$
L$_2$
L$_3$
24 V

Fill in the blanks below.

	LAMP 1	LAMP 2	LAMP 3	TOTAL
E				
I				
R	10 Ω	30 Ω	20 Ω	

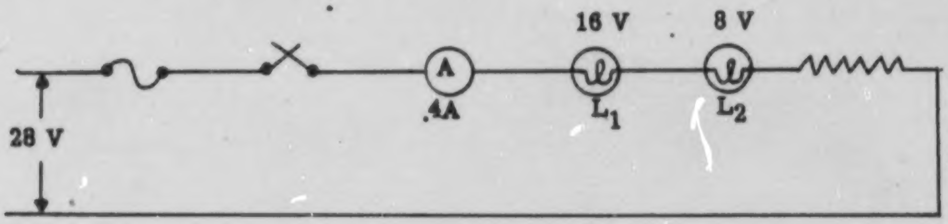
c. Problem No. 3.



Fill in the blanks below.

	LAMP	RESISTOR	TOTAL
E		16V	28V
I			.2A
R			

d. Problem No. 4.


16 V
8 V
A
.4A
L_1
L_2
28 V

Fill in the blanks below.

LAMP 1	LAMP 2	RESISTOR	TOTAL

WIRING PARALLEL CIRCUITS

OBJECTIVES

To aid you in gaining practical experience in wiring parallel circuits using electrical diagrams, using Ohm's Law in parallel circuits, and checking voltage and current in parallel circuits.

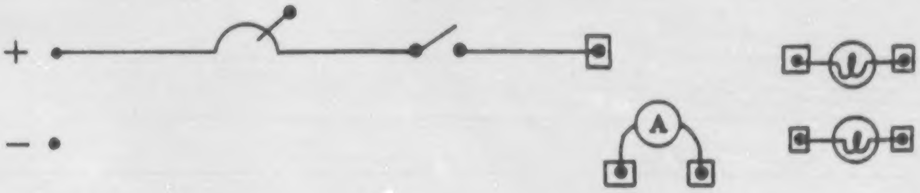
CAUTIONS

Remove jewelry

Turn power OFF before wiring circuits or before removing and adding circuit components.

Be sure of correct multimeter setting before making measurements.

1. In the space below, the units to be included in the circuit are a circuit breaker, an SPT Switch, an ammeter to indicate total current flow, and two lamps in parallel. Use lines to represent the wires you will place on the trainer.



2. Have the instructor check your diagram.

3. Wire the circuit on the trainer using your diagram as a guide.

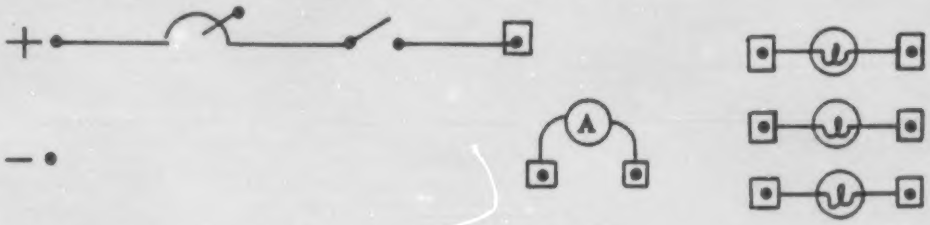
4. Have the instructor check your circuit.

NOTE: Circuit ammeter will be used to measure current. A multimeter will be used to measure voltage drops and applied voltage. Ohm's law will be used to determine resistance.

5. Turn the switch ON and complete the following for the circuit.

	LAMP 1	LAMP 2	TOTAL
E			
I			
R			

6. In the diagram below, use lines to represent how a third light would be wired in parallel to your circuit.



7. Have the instructor check your diagram.

8. Turn the switch ON and complete the following for the circuit.

	LAMP 1	LAMP 2	LAMP 3	TOTAL
E				
I				
R				

9. Remove the wires you place on the trainer.

10. Complete the following statements.

a. A parallel circuit is one with ____________ or more paths for current flow.

b. The voltage drop of a unit in a parallel circuit should be equal to the ________________ voltage.

c. Total current is the __________ of the currents from each path in a parallel circuit.

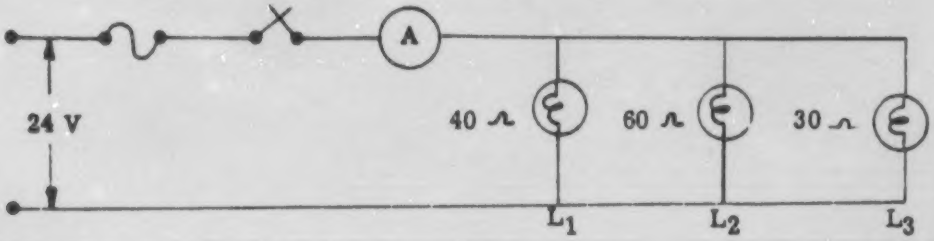
d. When additional units are added in parallel in a circuit, will the total resistance increase, decrease, or remain the same?

____

e. When units are added in parallel in a circuit, will the total current increase, decrease, or remain the same? ________________________

11. Solve the following problems using Ohm's law.

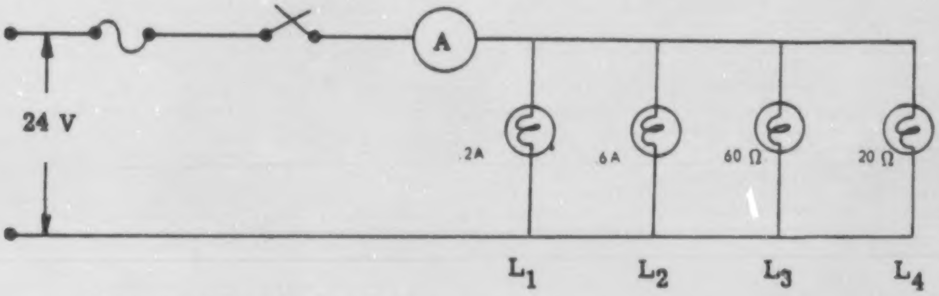
a. Problem No. 1.


A
24 V
40 Ω
60 Ω
30 Ω
L_1
L_2
L_3

Fill in the blanks below.

	LAMP 1	LAMP 2	LAMP 3	TOTAL
E				
I				
R				

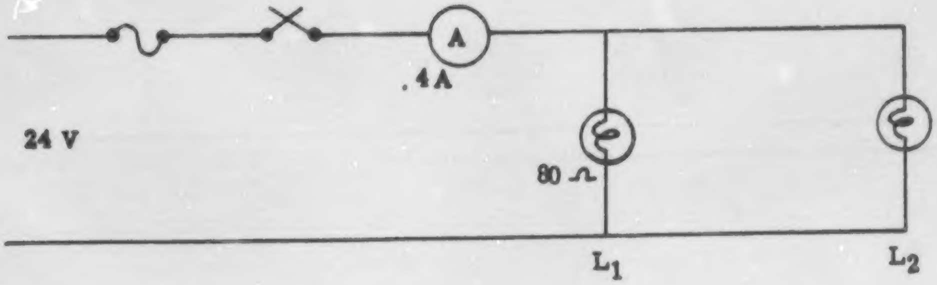
b. Problem No. 2.


A
24 V
.2A
.6 A
60 Ω
20 Ω
L_1
L_2
L_3
L_4

Fill in the blanks below.

	LAMP 1	LAMP 2	LAMP 3	LAMP 4	TOTAL
E					
I					
R					

c. Problem No. 3.


A
.4A
24 V
80 Ω
L1
L2

Fill in the blanks below.

	LAMP 1	LAMP 2	TOTAL
E			
I			
R			

WB 3ABR54530-II-1-P5
April 1975

CIRCUIT ANALYSIS

OBJECTIVES

This project will help you in learning to:

- Use electrical meters.
- Analyze electrical circuits to determine the location of opens, shorts, and low power.
- Determine defective electrical units.

PART I

1. When a wire is broken in a circuit, it is known as an __________ circuit.

2. What is the indication of an open circuit? ____________________

3. Meters that can be used to locate open circuits are

a. ____

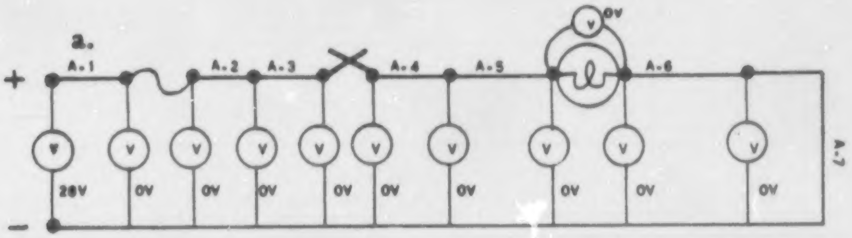
b. ____

c. ____

USING A VOLTMETER TO LOCATE OPENS

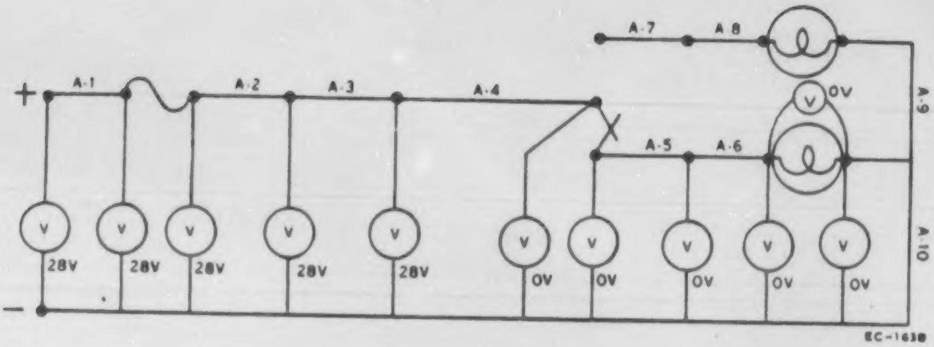
4. Study the diagrams below and list the location of the opens.

NOTE: Wires are identified by code, A-1, A-2, etc.



Location ____________________.

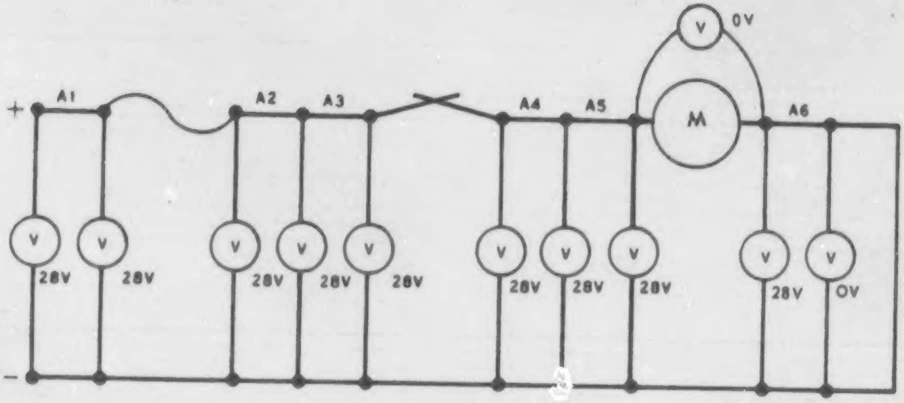
b.



+
−
A-1
A-2
A-3
A-4
A-5
A-6
A-7
A-8
A-9
A-10
V
28V
28V
28V
28V
28V
0V
0V
0V
0V
0V
0V
EC-1638

Location ____________________

c.



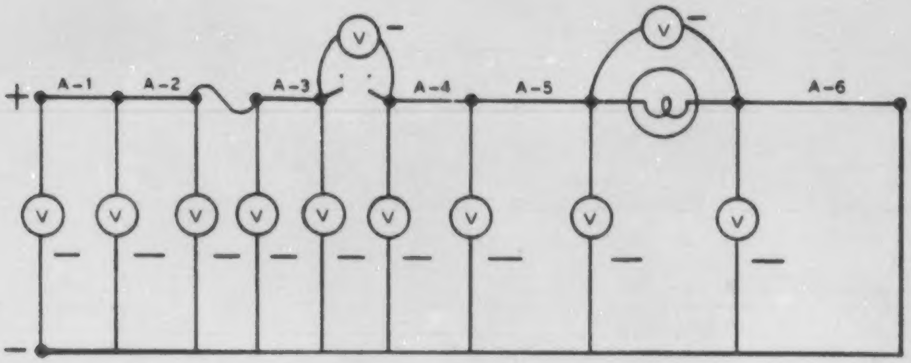
+
−
A1
A2
A3
A4
A5
A6
M
V
0V
28V
28V
28V
28V
28V
28V
28V
28V
28V
0V

Location ____________________

165

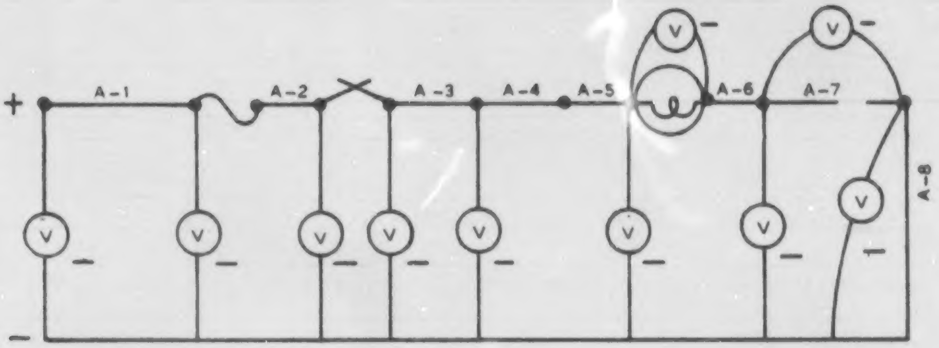
Study the diagrams below and write the correct voltmeter readings by each voltmeter on the circuits to indicate the location of the opens. (Use 28 volts.)

a. Location of open is switch.



+
A-1
A-2
A-3
A-4
A-5
A-6
V
–

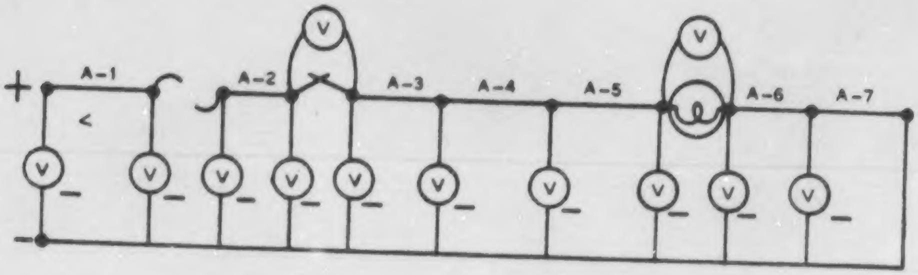
b. Location of open is A-7 wire.



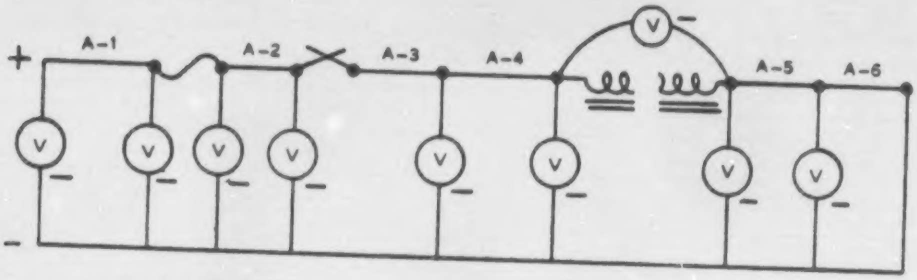
+
A-1
A-2
A-3
A-4
A-5
A-6
A-7
A-8
V
–

166

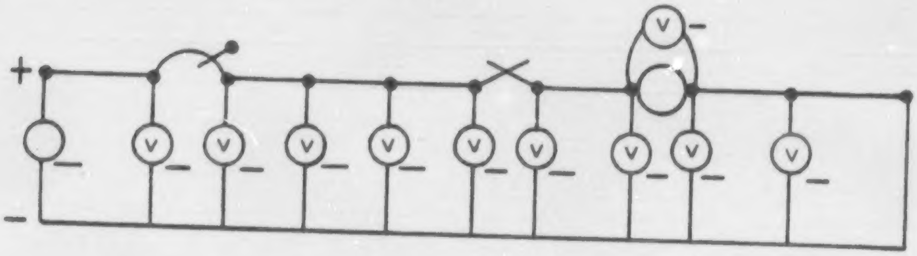
c. Location of open is fuse.


+
-
A-1
A-2
A-3
A-4
A-5
A-6
A-7
V

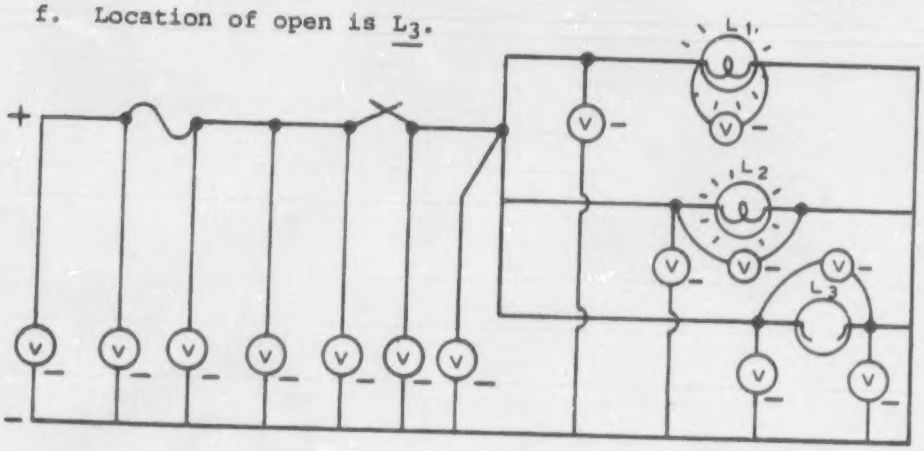
d. Location of open is coil.


+
-
A-1
A-2
A-3
A-4
A-5
A-6
V

e. Location of open is motor.



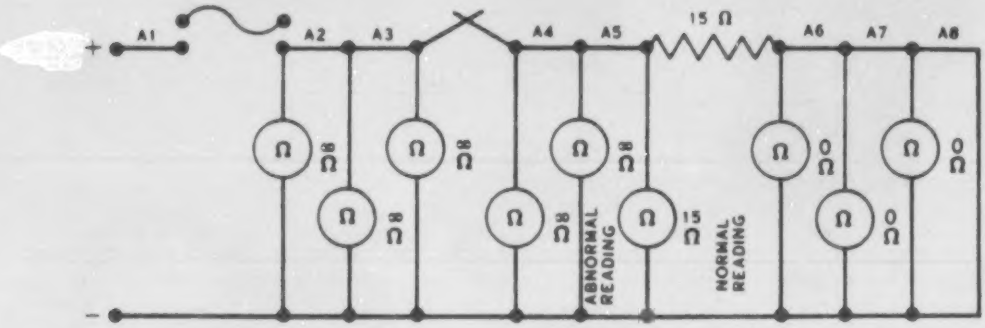
f. Location of open is L3.



USING THE OHMMETER TO LOCATE OPENS

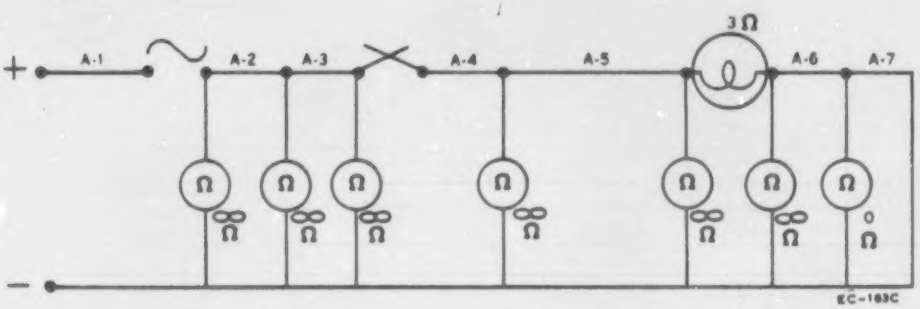
1. Study the diagrams below and list the location of the opens.

a.


+
A1
A2
A3
A4
A5
15 Ω
A6
A7
A8
∞ Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
15 Ω
0 Ω
0 Ω
0 Ω
ABNORMAL READING
NORMAL READING
−

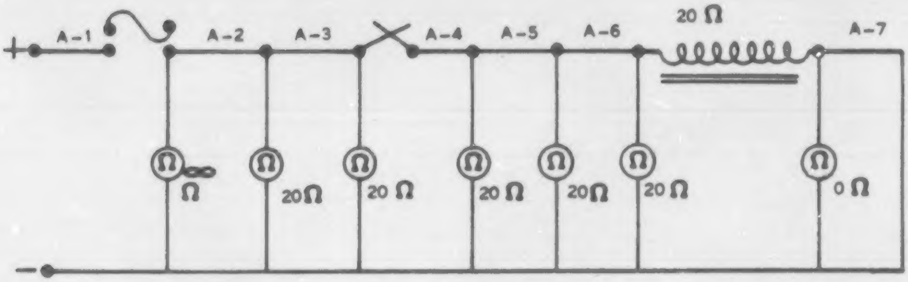
Location ______________________.

b.


+
A-1
A-2
A-3
A-4
A-5
3 Ω
A-6
A-7
∞ Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
∞ Ω
0 Ω
−
EC-163C

Location ______________________.

c.


+
A-1
A-2
A-3
A-4
A-5
A-6
20 Ω
A-7
∞ Ω
20 Ω
20 Ω
20 Ω
20 Ω
20 Ω
0 Ω
−

Location ______________________.

PART II

1. When a positive wire is grounded and causes current to be returned in shortcuts to the source of power, it is known as a __________ short.

2. A positive-to-positive short is called a __________ short when two independent circuits will operate from __________ switch.

3. A circuit that causes a fuse to blow or a circuit breaker to trip has a trouble called a __________ short.

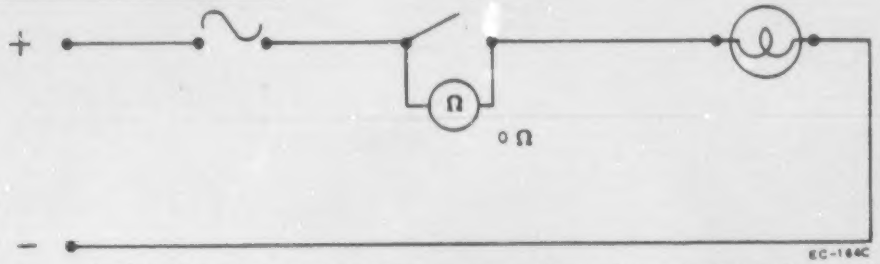
4. Meters that can be used to locate shorts are

   a. ______________________________

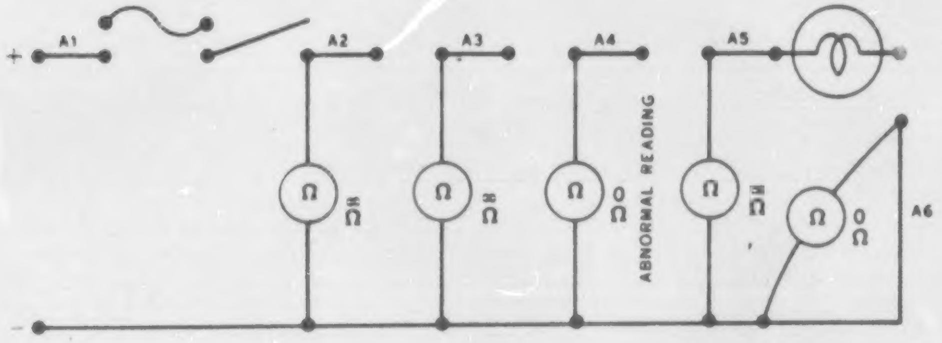
   b. ______________________________

5. Always __________________ a circuit before checking the circuit with an ohmmeter.

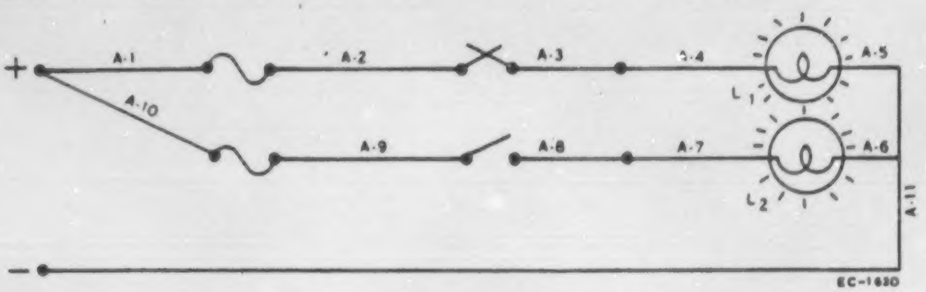
6. Study the diagram below. From the meter indication, the trouble is __________________.



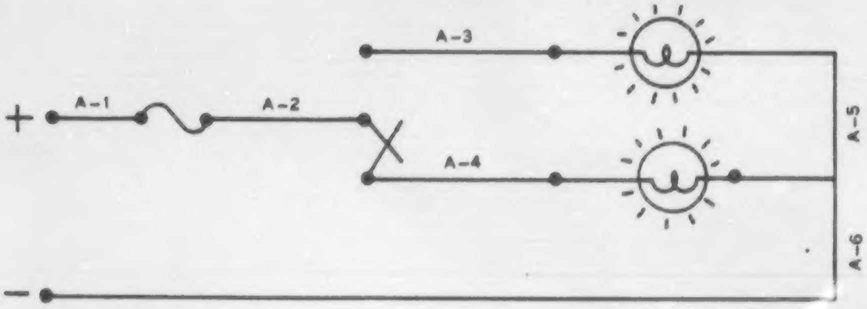
7. Study the diagram below. From the meter indications the trouble is a __________ short and its location is ____________________.



8. Study the diagram below. With your pencil, draw in a probable location of the short.


+
A-1
A-2
A-3
A-4
A-5
A-10
A-9
A-8
A-7
A-6
L1
L2
A-11
−
EC-1620

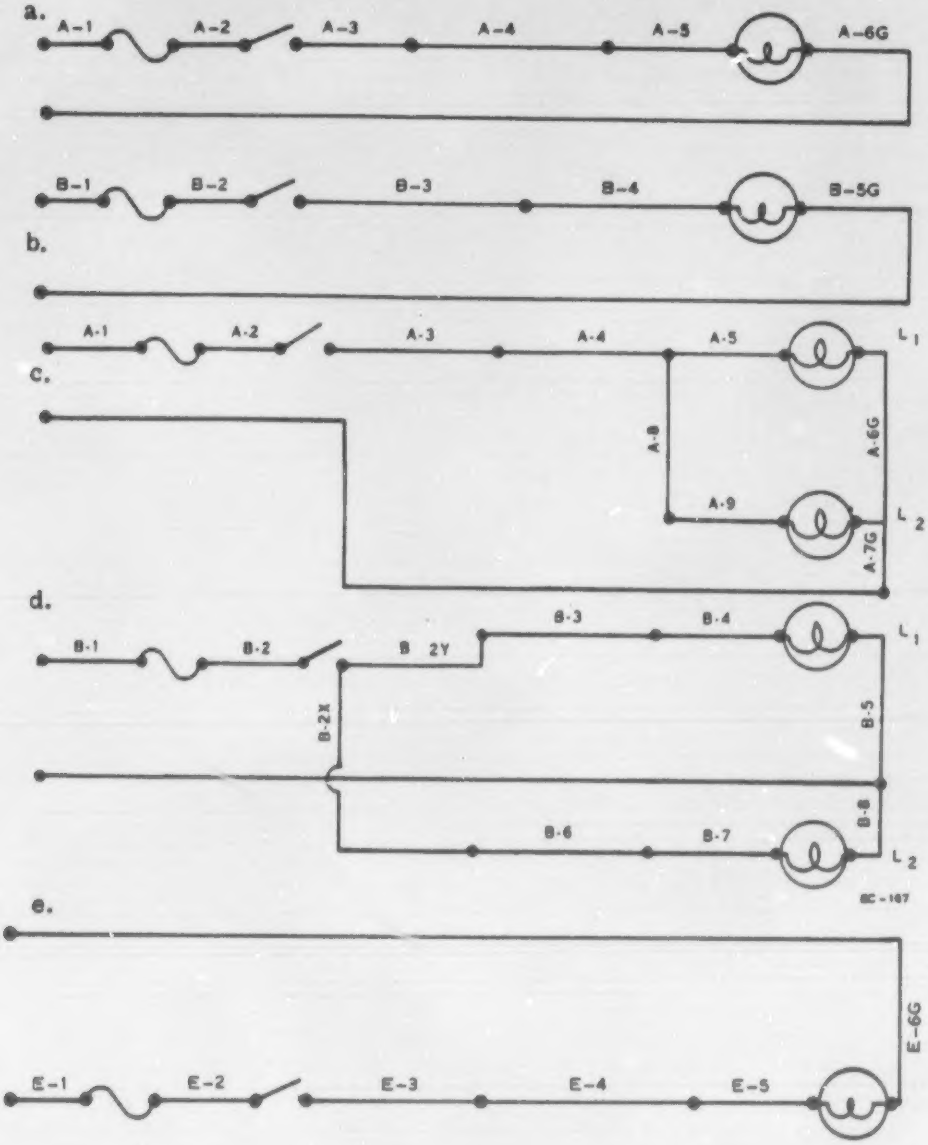
9. Study the diagram below. With your pencil, draw in a probable location of the short.


+
A-1
A-2
A-3
A-4
A-5
A-6
−

PART III

NOTE: The diagram following will aid you in determining possible locations of the trouble before you begin troubleshooting with the correct meter. For instance, if the trouble occurs in circuit "C," study the diagram of circuit "C" before using the meter to troubleshoot the circuit.

1. What meter would be used to check your analysis? ____________


a.
A-1
A-2
A-3
A-4
A-5
A-6G
B-1
B-2
B-3
B-4
B-5G
b.
A-1
A-2
A-3
A-4
A-5
L1
c.
A-8
A-6G
A-9
L2
A-7G
d.
B-3
B-4
L1
B-1
B-2
B 2Y
B-2X
B-5
B-8
B-6
B-7
L2
EC-167
e.
E-6G
E-1
E-2
E-3
E-4
E-5

A diagram of the Trainer

NOTE: On the trainer assigned to you, be sure all the trouble switches to your left are OFF. Operate all circuits. No troubles should exist. Now you are ready to troubleshoot. Begin by turning trouble switch No. 1 ON. Operate all circuits and determine the defective circuit. Fill in the blanks below.

TROUBLE SWITCH	DEFECTIVE CIRCUIT OR CIRCUITS (List letter of circuit, A-E)	TYPE OF TROUBLE	LOCATION
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Checked by ____________________
(Instructor)

2TPT-3101-07

Prepared by:
Instructional Systems Development Team
Sheppard AFB, Texas

Technical Training

DEPARTMENT OF CIVIL ENGINEERING TRAINING

Basic Electricity,
Ohm's Law, and
DC Power

July 1967

11-6

Designed For ATC Course Use

PURPOSE OF STUDENT STUDY GUIDES AND STUDENT WORKBOOKS

Student Study Guides and Student Workbooks are training publications authorized by Air Training Command (ATC) for student use in ATC courses.

The STUDENT STUDY GUIDE (SSG) presents the information you need to complete the unit of instruction, or makes assignments for you to read in other publications which contain the required information.

The STUDENT WORKBOOK (SWB) contains work procedures designed to help you achieve the learning objectives of the unit of instruction. Knowledge acquired from using the student study guide will help you perform the missions or exercises, solve the problems, or answer questions presented in the workbook.

The STUDENT STUDY GUIDE AND WORKBOOK (SSG/WB) contains both SSG and SWB material under one cover. The two training publications may be combined when the SWB is not designed for you to write in, or when both SSG and SWB are issued for you to keep.

SSGs and SWBs are designed for ATC course use only. They are updated as necessary for training purposes, but are NOT to be used on the job as authoritative references in preference to Technical Orders or other official publications.

VALIDATION DATA

This programmed text on Basic Electricity, Ohm's Law, and DC Power has been validated on 75 students. Target population consisted of 35 A3C students awaiting formal training and 40 students enrolled in ABR 54330, Electrical Power Production.

The criterion test has a total of 32 responses, with 30 out of 32 being the standard of performance. Any 30 correct responses is 100%.

The following results indicate time taken to complete the program and scores obtained on the criterion test.

	Range	Average
Time	25 - 90 Minutes	53 Minutes
Scores	40% - 100%	96.2%

175

- Objectives -

After completing this unit of instruction, you will be able to accomplish the following:

- Definition of a basic electrical circuit
- Three basic parts of a circuit
- Two devices used for circuit protection
- Device used to control the circuit
- Twelve electrical symbols
- Definition of a voltmeter
- Method of connecting a voltmeter in a circuit
- Definition of an ammeter
- Method of connecting an ammeter in a circuit
- Definition of Ohm's Law
- Formula for determining current value in a circuit
- Formula for determining voltage values in a circuit
- Formula for determining resistance value in a circuit
- Definition of power
- Unit of measure for true electrical power
- Formula for determining true power in a DC circuit
- Use applied voltage and total current flow to compute the amount of power consumed in a DC circuit
- Four electrical safety precautions when working on electrical circuits

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1. As a Power Production Specialist, you will have occasion to work on electrical circuits. Understanding electrical circuitry is easy if you understand and utilize principles that always apply.

For example:

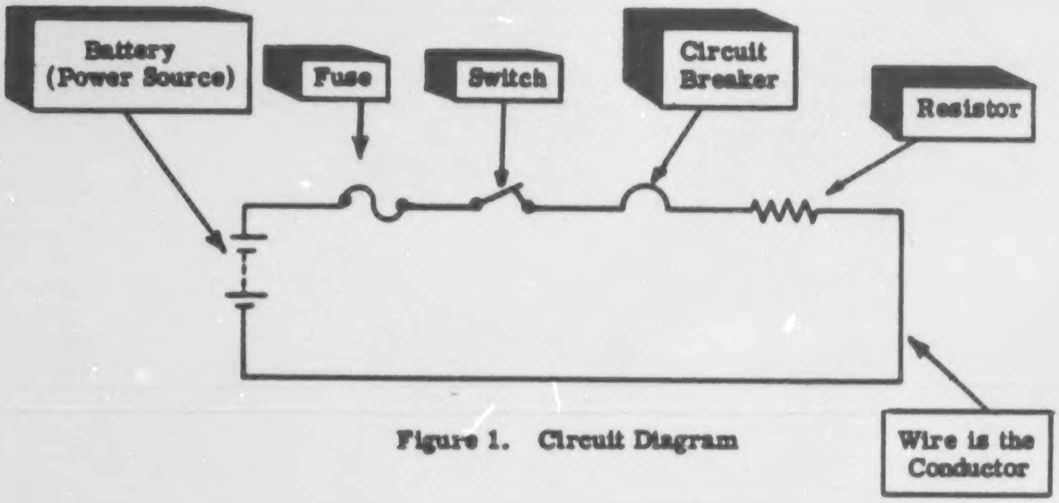


Figure 1. Circuit Diagram

Principles

1. **Definition of an Electrical Circuit:** An electrical circuit is defined as a closed path of current flow.

2. **A Basic Electrical Circuit:** The three basic parts of an operational circuit consist of a power source, conductor, and a unit of resistance which form a closed (complete) path for current flow. (See Fig. 1.)

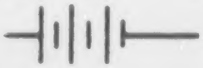
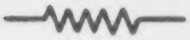
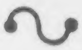
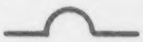
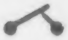
3. **Protective Devices:** Protective devices protect circuits in case of overloads or malfunctions. Protective devices consist of fuses and circuit breakers.

4. **Switches:** A switch is a device used to control the circuit by making or changing connections.

Carefully study Figure 1 and the four principles, then turn the page and answer the following questions.

2. Electrical circuits are represented by wiring diagrams where symbols are used to identify specific electrical units, just as symbols are used to identify objects on a road map.

2.1 Refer to the circuit diagram and principles on the previous page and write the name beside each of the following symbols, and label those that are protective devices with a "P":

	Symbols	Name	Protective Devices
a.		____________________	____
b.		____________________	____
c.		____________________	____
d.		____________________	____
e.		____________________	____

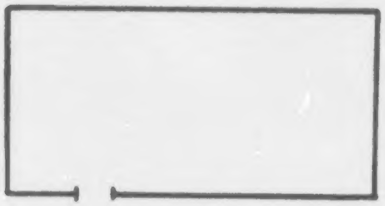


Figure 2

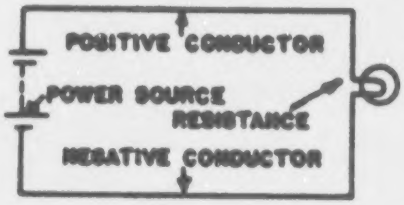


Figure 3

2.2 Place an "X" beside each of the following True statements:

____ a. Figure 2 above is an electrical circuit.

____ b. Figure 3 above is a basic electrical circuit.

____ c. Figure 2 is not an electrical circuit because it is open and therefore not a complete path for current flow.

____ d. Figure 3 has the 3 basic parts of an electrical circuit.

Answers: 2.1
a. battery
b. resistor
c. fuse P
d. circuit breaker P
e. switch

2.2
X b.
X c.
X d.

2.3

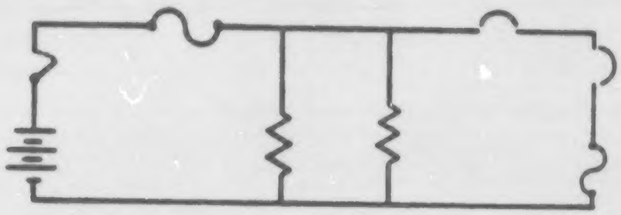


Figure 4

Refer to Figure 4 above and place an "X" beside each True statement listed below:

____ a. If the switch is in the closed position there would be a complete path for current flow.

____ b. There are four protective devices in the circuit.

____ c. There is a power source, conductors, and two resistors in the circuit.

____ d. There is only one control device in the circuit.

2.4 Write the missing items in the following statements: (Refer to Figure 4 if necessary)

a. An electric circuit is defined as having a ____________ path for current flow.

b. The three basic parts of a circuit are the ____________ source, ____________, and units of ____________.

c. Two devices used for circuit protection are ____________ and ____________.

d. The device used to control the circuit is the ____________.

2.5 The three basic or essential parts of an electrical circuit are

____ a. fuses, conductors, and switches.
____ b. power source, resistance, and conductors.
____ c. battery, insulators, and resistance.
____ d. fuses, power source, and conductors.

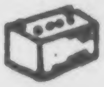
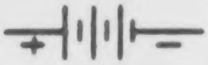
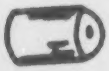
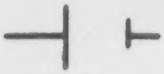
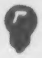
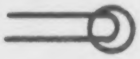
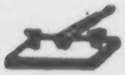
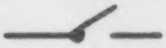
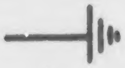
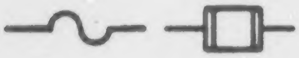
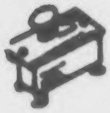
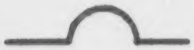
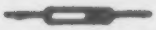
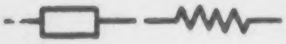
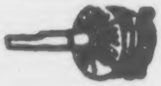
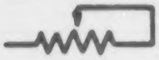
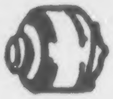
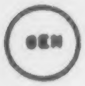
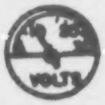
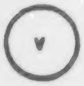
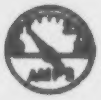
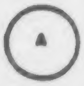
Answers:

2.3 X a.
X b.
X c.
X d.

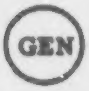
2.4 a. complete
b. power, conductors, resistance
c. fuses, circuit breakers
d. switch

2.5 X b.

3. Much of your time will be spent troubleshooting equipment you are required to maintain. In order to understand how a system or a component operates, you must be able to identify the following electrical devices and their symbols:

	Device	Illustration	Symbol
1.	Battery		
2.	Battery Cell		
3.	Lamp		
4.	Switch		
5.	Ground		
6.	Fuse		
7.	Circuit Breaker		
8.	Fixed Resistor		
9.	Rheostat		
10.	D. C. Generator		
11.	Voltmeter		
12.	Ammeter		

3. **Refer to the previous page (only if you need to) and label each of the following symbols:**



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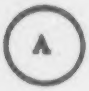

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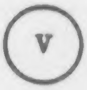

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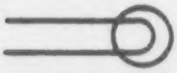

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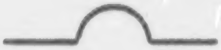

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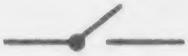

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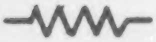

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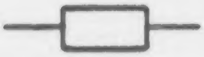

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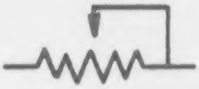

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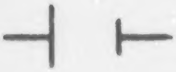

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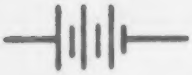

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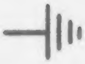

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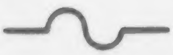

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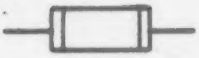

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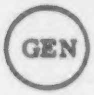
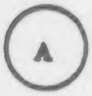
Turn the page and check your answers

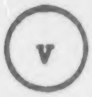
Answer: **3.1**



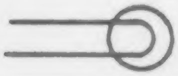
Generator



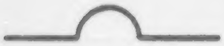
Ammeter



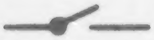
Voltmeter



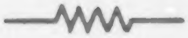
Lamp



Circuit Breaker



Switch



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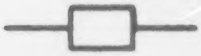

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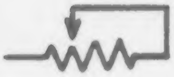
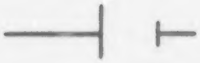
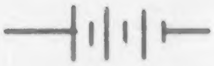


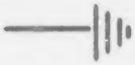
Rheostat



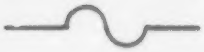
Battery Cell



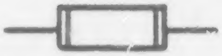
Battery



Ground

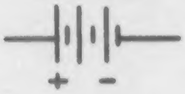
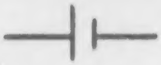
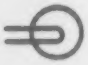
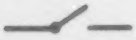
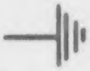
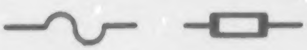
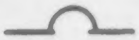
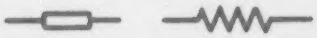
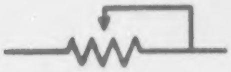
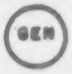
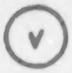
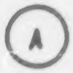


Fuse

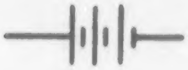
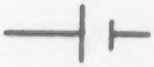
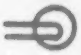
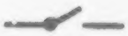
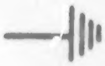
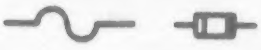
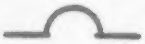
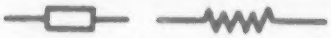
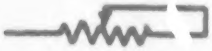
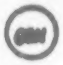
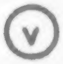
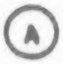


Fuse

3.2 Match each electrical device with its symbol by placing the number of the device in the appropriate blank.

Devices		Symbol
1. D. C. Generator	____	
2. Ammeter	____	
3. Ground	____	
4. Battery Cell	____	
5. Voltmeter	____	
6. Switch	____	
7. Rheostat	____	
8. Circuit Breaker	____	
9. Fuse	____	
10. Lamp	____	
11. Fixed Resistor	____	
12. Battery	____	

Answers: 3.2

	Devices		Symbol
1.	D.C. Generator	12	
2.	Ammeter	4	
3.	Ground	10	
4.	Battery Cell	6	
5.	Voltmeter	3	
6.	Switch	9	
7.	Rheostat	8	
8.	Circuit Breaker	11	
9.	Fuse	7	
10.	Lamp	1	
11.	Fixed resistor	5	
12.	Battery	2	

MEASUREMENT OF VOLTAGE

4. **Measurement of Voltage (EMF):** The instrument for measuring voltage is the VOLTMETER. Figure 6 illustrates the correct way of using the voltmeter to read the voltage drop of the load resistor. Note that the voltmeter is connected directly across the load - in parallel.

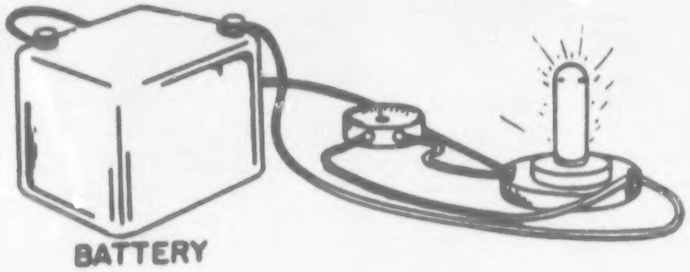


Figure 6. Voltmeter Connection

4.1 A voltmeter is a device used to measure the difference in __________ __________ force between two points in a circuit.

4.2 To connect a voltmeter in a circuit, you would always connect it in (circle one) __________ with the load.

series - parallel

Remember, a voltmeter is connected in parallel directly ACROSS the load to measure its voltage drop. When connecting a voltmeter across a battery, connect positive to positive, and negative to negative. (This is referred to as proper polarity). To measure voltage output of a power source the voltmeter is connected across the output terminals of the power source.

4.3

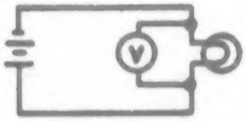


Figure 7

The voltmeter in Figure 7 is connected in (select one)

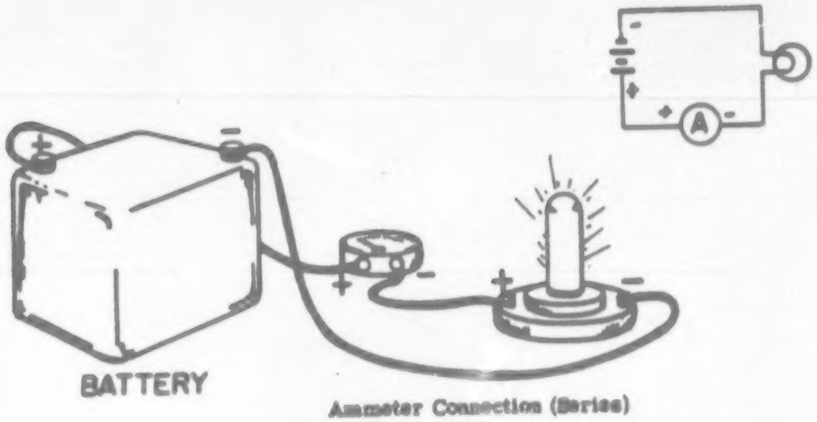
___ a. parallel with the load.

___ b. series with the load.

Answers: 4.1 electromotive 4.2 parallel 4.3 X a.

MEASUREMENT OF CURRENT

5. Current is measured with an AMMETER. Figure 8 illustrates the proper way of connecting the ammeter. The instrument is put in SERIES with the load (resistance) so that the total current flows through it. Notice that the positive terminal of the ammeter is connected to the positive terminal of the battery. If the connections were reversed, the meter would deflect in the wrong direction and the impact of the needle against the stop marker might bend it considerably.



Ammeter Connection (Series)

Figure 8.

5.1 The ammeter is used in a circuit to measure

____ a. voltage.

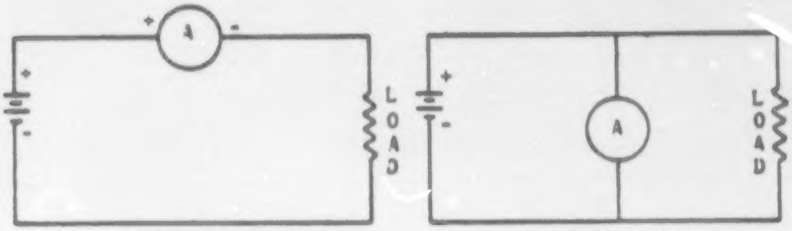
____ b. resistance.

____ c. current.

____ d. power.

Answer: 5.1 _X_ c.

6. **Part B of Figure 9 shows the WRONG way of using the ammeter. Notice that, with this circuit, the ammeter is directly across the battery terminals. The meter is not designed to withstand even moderately high voltages. Consequently, connecting an ammeter across the line will usually burn out the meter movement.**



A - Correct Use B - Incorrect Use

Figure 9

6.1 **In which schematic diagram in Figure 10 below is the ammeter properly connected - (1), (2), or (3) ?** ____________________

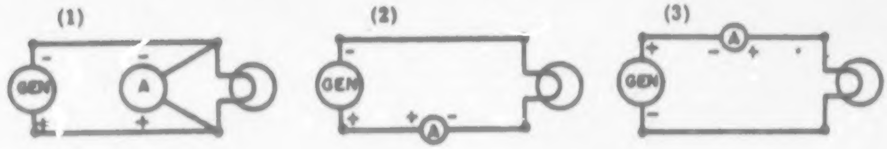


Figure 10

Answer: 6.1 (2)

6.2 To measure the current flow in a circuit, you would connect the ammeter in

____ a. Parallel with the load by connecting the negative side of circuit and positive lead to positive side.

____ b. Series with the load by connecting the negative lead to positive side of the circuit and positive lead to negative side.

____ c. Parallel with the load by connecting negative lead to positive side of circuit and positive lead to negative side.

____ d. Series with the load by connecting the negative lead to negative side of circuit and positive lead to positive side.

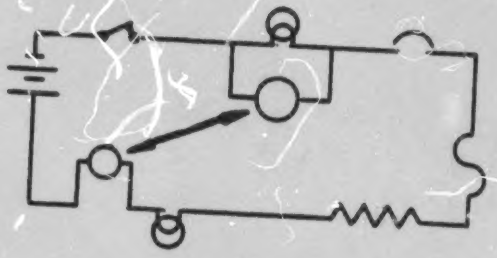
Answer: 6.2 X d.

6.3 Label the voltmeter and ammeter that are properly connected in the following circuits and

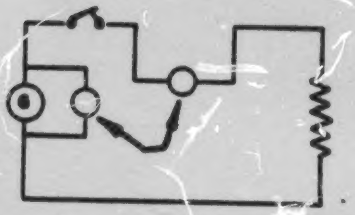
write Ⓥ and Ⓐ

to identify the device used:

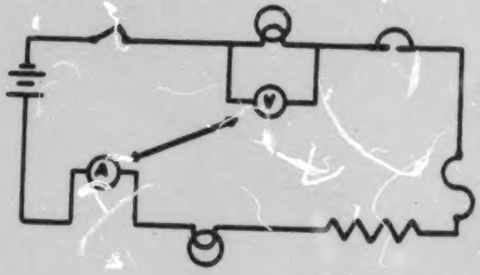
A.



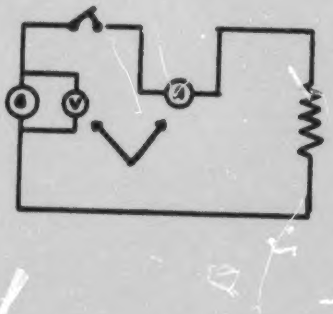
B.



Answer: 6.3a



6.3b



7. There is a definite relationship between Current (I), Voltage (E), and Resistance (R) in any circuit. This relationship is known as Ohm's Law.

> Ohm's Law states that current varies directly with the voltage and inversely with the resistance.

From this law you can see that there are two separate relationships that affect current:

- a. The relationship of current and voltage (current varies directly with the voltage).
- b. The relationship of current and resistance (current varies inversely with the resistance).

First let's discuss the first relationship - that of current and voltage. We said that current varies directly with the voltage. Simply stated this means that current increases as voltage is increased. The reverse is also true.

7.1 Place an X by the true statements.

____ a. When voltage increases, current decreases.

____ b. Current varies inversely with the voltage.

____ c. Current varies directly with the voltage.

____ d. When voltage decreases current decreases.

Answer: 7.1
X c.
X d.

The second relationship that affects current is that of current and resistance. We said that current varies inversely with the resistance. This means that current decreases as resistance is increased. Inversely in this sense means that, as one value (resistance) increases, the other value (current) decreases. The reverse is also true.

7.2 Place an X by the true statements.

____ a. Current varies inversely with resistance.

____ b. Current increases as resistance is increased.

____ c. Current increases as resistance is decreased.

____ d. Current varies directly with the resistance.

7.3. Complete Ohm's Law by inserting the missing words in the spaces provided.

Ohm's Law states that current ________ ________ with the voltage and ________ with the resistance.

Answers: 7.2 X a.
X c.

7.3 varies directly
inversely

8. Ohm's Law is expressed in formulas. These formulas are used to solve for values of current, voltage, and resistance in circuits. Before you can use these formulas you must learn the symbols for current, voltage, and resistance.

The electrical symbol for current is the letter I.

The electrical symbol for voltage or electromotive force is E.

The electrical symbol for resistance is R.

8.1 a. E is the electrical symbol for ______________ ________ or ______________.

b. I is the electrical symbol for ________________.

c. R is the electrical symbol for ________________.

Answers: 8.1

a. electromotive force or voltage
b. current
c. resistance

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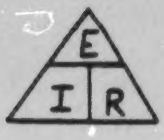
9. The Ohm's Law triangle will help you understand the relationship of current, voltage, and resistance. It will also aid you in determining the correct formulas for solving problems of electrical values.



The letters of this triangle are arranged into the following formulas to show the relationship of current, voltage, and resistance.

a. The formula for computing voltage is $E = I \times R$.

b. The formula for computing resistance is $R = E/_I$.

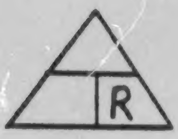
9.1 Now you use the Ohm's Law triangle to determine the formula for current. Write your answer in the space provided.

$I =$

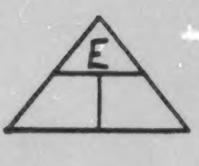
Answer: 9.1 $I = E/_R$

9.2 In the incomplete Ohm's Law triangles below, fill in the missing letters.

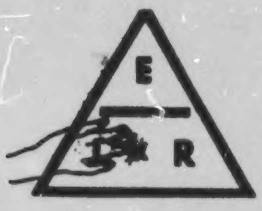
a.



b.

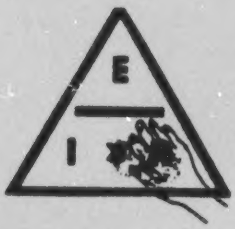


The three equations will enable you to find any one of the three factors (current, voltage, or resistance) if you know the other two. An easy way to remember the three relationships is to use the Ohm's Law triangle as shown in Figure 11 below.



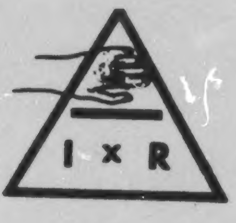
TO FIND I (AMPERES) PLACE THUMB OVER I AND DIVIDE E BY R AS INDICATED

$$I = \frac{E}{R}$$



TO FIND R (OHMS) PLACE THUMB OVER R AND DIVIDE AS INDICATED

$$R = \frac{E}{I}$$



TO FIND E (VOLTS) PLACE THUMB OVER E AND MULTIPLY AS INDICATED

$$E = I \times R$$

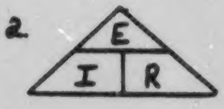
By placing your finger over the unknown factor, the relative positions of the other two known factors will tell you what to do.

If one is above the other, divide. If they are beside each other, such as I and R, then multiply.

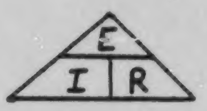
Figure 11 explains this in detail.

Answer: 9.2

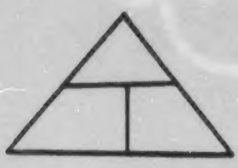
a.



b.



9.3 **In the blank Ohm's Law triangle below, fill in all the symbols for current, voltage, and resistance.**



9.4 **Using the letters you inserted in the triangle - complete the formula for computing voltage.**

E = ________ x _______.

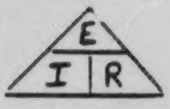
9.5 **Again, using the letters in the triangle, complete the formula for computing current.**

I = __________

9.6 **Complete the formula for resistance.**

R = ______ / ______

Answers: **9.3**



9.4 **E = I x R** **9.5** **I = $E/_R$**

9.6 **R = $E/_I$**

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10.1 Place each symbol in the Ohm's Law triangle next to the term it represents:

___ Power

___ Resistance

___ Electron

___ Voltage

___ Current

___ Ion

10.2 The formula for computing current in a circuit is

___ a. $I = E \times R$

___ b. $I = E/_{R}$

___ c. $R = E/_{I}$

___ d. $I = R/_{E}$

10.3 The formula for computing voltage in a circuit is

___ a. $E = I/_{R}$

___ b. $R = E/_{I}$

___ c. $E = R/_{I}$

___ d. $E = I \times R$

10.4 The formula for computing resistance in a circuit is

___ a. $I = E/_{R}$

___ b. $R = I/_{E}$

___ c. $R = E/_{I}$

___ d. $R = E \times I$

Answers: 10.1 R Resistance
E Voltage
I Current

10.2 X b.
10.3 X d.
10.4 X c.

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11.1 Complete the following statements.

a. The formula for computing current in a circuit

is ______________.

b. The formula for computing voltage in a circuit

is ______________.

c. The formula for computing resistance in a circuit

is ______________.

Answers: 11.1 a. $I = E/_{R}$

b. $E = I \times R$

c. $R = E/_{I}$

D C POWER

12. Power is simply defined as the rate of doing work. The unit of measure for true electrical power is the watt or kilowatt. A kilowatt equals 1000 watts. A 100-watt electric light bulb requires about 1 ampere of current. A 10 horsepower motor requires about 75 amperes or, roughly, 7500 watts.

12.1 Power is defined as the

____ a. rate of energy used.

____ b. rate of time required to use energy.

____ c. rate of doing work.

____ d. rate of work required for a horsepower.

12.2 The watt is a unit of measure for

____ a. apparent power.

____ b. voltage.

____ c. total amperes.

____ d. true power.

Answer: 12.1 X c.

12.2 X d.

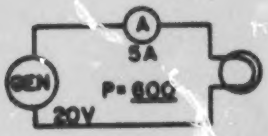
13. It is important to know the values of voltage, current, and resistance in a circuit, although we are really more concerned with electrical power (watts). To determine the watts of electrical power being consumed in a circuit, the power formula P = E x I may be used.

P = Watts

E = Voltage (measured in volts)

I = Current (measured in Amperes)

A circuit with an applied voltage of 120 volts and a current flow of 5 amperes, will consume 120 x 5 or 600 watts.



13.1 A formula for computing DC power is

___ a. $P = I \times R$

___ b. $P = \frac{E}{R}$

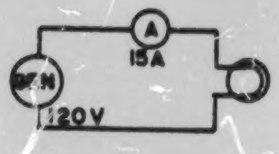
___ c. $P = E \times I$

___ d. $P = \frac{E}{I}$

Answer: 13.1 _X_ c.

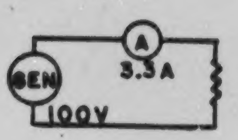
13.2 Compute and enter the value of power of the following schematic diagrams in the spaces provided.

a.


A
15A
GEN
120V

P = _____ watts

b.


A
3.3A
GEN
100V

P = _____ watts

13.3 The formula for computing DC power is

____

Answer: 13.2 a. P = 1800 watts 13.3 P = E x I

b. P = 330 watts

14. Most electrical injuries are caused by carelessness or overconfidence in handling equipment. Most personnel are likely to think in terms of high voltage, but death lies in the low voltages too.

Electric shock may cause instant death or unconsciousness, cessation of breathing, and burns of all degrees.

SAFETY PRECAUTIONS WHEN WORKING ON ELECTRICAL CIRCUITS ARE:

- Use insulating matting
- Remove hand jewelry
- Wear dry clothing
- Avoid touching exposed terminals

Safety is a part of everyone's job. It is the responsibility of every person to exercise precautions to insure that personnel will not be injured or killed.

14.1 Place an X by the four electrical safety precautions to be observed when working on electrical circuits.

___ a. Wear steel-capped safety shoes when working on electrical equipment.

___ b. Stand on insulated matting.

___ c. Use cloth matting.

___ d. Remove rings, watches, etc.

___ e. Wear rubberized suit at all times while working on electrical circuits.

___ f. Wear dry clothing.

___ g. Use both hands while touching exposed terminals.

___ h. Avoid touching exposed terminals.

Answer: 14.1

X b.
X d.
X f.
X h.

CRITERION EXAMINATION

(Place a check (✓) by the correct answer in the following questions)

1. An electrical circuit is defined as having a

___ a. potential voltage and resistance.

___ b. complete path for current flow.

___ c. complete path for resistance.

___ d. set of fuses and switches.

2. The three essential parts of an electrical circuit are

___ a. conductors, fuses, and switches.

___ b. fuses, power source, and conductors.

___ c. power source, resistance, and conductors.

___ d. insulators, power source, and resistance.

3. Two devices used for protection of an electrical circuit are

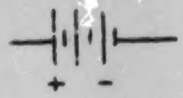
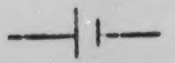
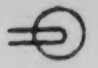
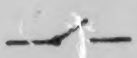
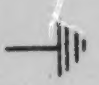
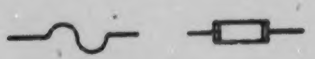
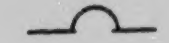
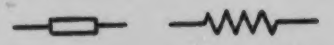
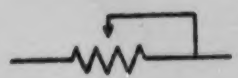
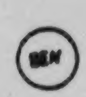
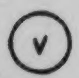
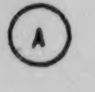
___ a. insulators and switches.

___ b. circuit breakers and switches.

___ c. fuses and circuit breakers.

___ d. switches and fuses.

4. Match each electrical device with its symbol by placing the number of the device in the appropriate blank.

	Devices		Symbol
1.	D. C. Generator	____	
2.	Ammeter	____	
3.	Ground	____	
4.	Battery Cell	____	
5.	Voltmeter	____	
6.	Switch	____	
7.	Rheostat	____	
8.	Circuit Breaker	____	
9.	Fuse	____	
10.	Lamp	____	
11.	Fixed Resistor	____	
12.	Battery	____	

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5. The component used to control an electrical circuit is a

____ a. fuse.

____ b. fixed resistor.

____ c. switch.

____ d. voltmeter.

6. The device used to measure the difference in electromotive force between two points in a circuit is the

____ a. voltmeter.

____ b. ammeter.

____ c. ohmmeter.

____ d. wattmeter.

7. The method used to connect a voltmeter in a circuit is by connecting it in

____ a. parallel with the load.

____ b. series with the load.

____ c. front of the load.

____ d. back of the load.

8. To measure the current flow in a circuit, you would use a/an

____ a. voltmeter.

____ b. ammeter.

____ c. ohmmeter.

____ d. wattmeter.

9. To measure the current flow in a circuit, you would connect the ammeter in

____ a. series with the load by connecting the negative lead to negative side of circuit and positive lead to positive side.

____ b. series with the load by connecting the negative lead to positive side of the circuit and positive lead to negative side.

____ c. parallel with the load by connecting the negative lead to negative side of circuit and positive lead to positive side.

____ d. parallel with the load by connecting negative lead to positive side of circuit and positive lead to negative side.

10. Ohm's Law states that current varies

____ a. directly with the voltage and inversely with the resistance.

____ b. inversely with the voltage and directly with the resistance.

____ c. directly with the resistance and inversely with the power.

____ d. inversely with the resistance and directly with the power.

11. The formula for computing current value in a circuit is

____ a. $I = \frac{E}{R}$

____ b. $E = I \times R$

____ c. $I = E \times R$

____ d. $R = \frac{E}{I}$

12. The formula for computing voltage values in a circuit is

____ a. $I = \frac{E}{R}$

____ b. $E = I \times R$

____ c. $R = \frac{E}{I}$

____ d. $P = I \times E$

13. The formula for computing resistance in a circuit is

____ a. $I = \frac{E}{R}$

____ b. $E = I \times R$

____ c. $R = \frac{E}{I}$

____ d. $R = E \times I$

14. Power is defined as the

____ a. rate of doing work.

____ b. amount of energy used.

____ c. time required to use energy.

____ d. work required for a horsepower.

15. The watt is a unit of measure for

____ a. apparent power.

____ b. resistance.

____ c. true power.

____ d. kilowatt amperes.

16. The formula for computing DC power is

___ a. P = I x R

___ b. P = $\frac{E}{R}$

___ c. P = I x E

___ d. P = $\frac{E}{I}$

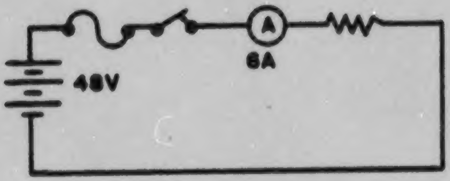
17. The amount of power consumed in this DC circuit is

___ a. 88 watts.

___ b. 188 watts.

___ c. 288 watts.

___ d. 388 watts.



18. Check (√) the four electrical safety precautions that should be observed when working on electrical circuits.

___ a. Use insulating matting

___ b. Use any type of matting

___ c. Remove hand jewelry

___ d. Wear dry clothing

___ e. Have potential voltage at all times

___ f. Have meters available

___ g. Never compute voltage of a line circuit

___ h. Avoid touching exposed terminals

2TPT-3101-08

Technical Training

DEPARTMENT OF CIVIL ENGINEERING TRAINING

D C Series Circuits

February 1969

11-6

Designed For ATC Course Use

PURPOSE OF STUDY GUIDES AND WORKBOOKS

Study Guides and Workbooks are training publications authorized by Air Training Command (ATC) for student use in ATC courses.

The STUDY GUIDE (SG) presents the information you need to complete the unit of instruction, or makes assignments for you to read in other publications which contain the required information.

The WORKBOOK (WB) contains work procedures designed to help you achieve the learning objectives of the unit of instruction. Knowledge acquired from using the student study guide will help you perform the missions or exercises, solve the problems, or answer questions presented in the workbook.

THE STUDY GUIDE AND WORKBOOK (SG/WB) contains both SG and WB material under one cover. The two training publications may be combined when the WB is not designed for you to write in, or when both SG and WB are issued for you to keep.

Training publications are designed for ATC use only. They are updated as necessary for training purposes, but are NOT to be used on the job as authoritative references in preference to Technical Orders or other official publications.

VALIDATION DATA

This programmed text on DC Series Circuits has been validated on 33 airmen enrolled in ABR 54330, Electrical Power Production Course.

The Criterion Examination has a total of 15 responses, with 14 out of the 15 being the standard of performance. Fourteen correct responses is 100%.

The following results indicate time taken to complete the program and scores obtained on the Criterion Examination.

	RANGE	AVERAGE
TIME	25 - 90 Minutes	54 Minutes
SCORE	80 - 100%	94%

Ninety-four percent of the students scored 90% or better.

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- Learning Objectives -

After completing this unit of instruction you will be able to accomplish the following:

- Recognize from a list of statements the one that defines a series circuit as having only one path for current flow.

- Identify from a list of statements the characteristics of a series circuit as being:

  - Current flow will be the same throughout the circuit.

  - Applied voltage is equal to the sum of the voltage drops across all resistors.

  - Total resistance is equal to the sum of the individual resistors.

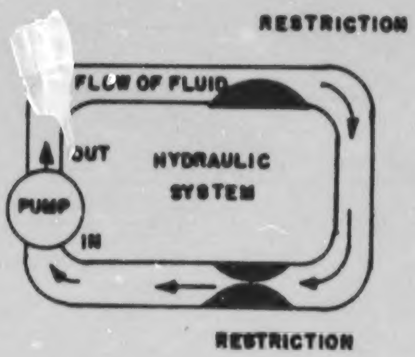
- Solve for unknown values of voltage, current, resistance, and power using electrical formulas and circuit characteristics when given series circuit schematics and sufficient known values.

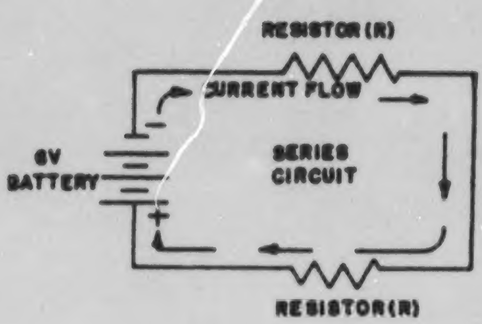
INTRODUCTION

In any type of work that utilizes the effects of electron flow, a knowledge of series circuits is desirable. None of the effects accompanying electron flow . . . . heating, lighting, or magnetic effects . . . would be possible without the use of electrical circuits.

Many electrical devices can be utilized more effectively if the operator has a knowledge of the circuits used to supply the current for the operation of the device. The purpose of this package is to give, in simplified form, conventional methods of solving problems involving current, voltage, and resistance by the use of basic formulas and the characteristics of the series circuit.

In the drawings below, you will see how a series circuit compares to a hydraulic system.


RESTRICTION
FLOW OF FLUID
OUT
HYDRAULIC SYSTEM
PUMP
IN
RESTRICTION


RESISTOR (R)
CURRENT FLOW
6V BATTERY
SERIES CIRCUIT
RESISTOR (R)

You will notice that in both drawings the fluid or current has only one path to flow.

Check (✓) the true statement.

( ) 1. A circuit that has two or more resistors connected end-to-end to form two separate paths for current flow is a series circuit.

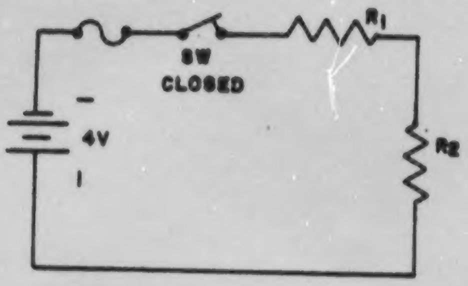
( ) 2. A circuit that has one or more resistors connected to provide only one path for current flow is a series circuit.

( ) 3. A circuit with two or more resistors each providing a separate path for current flow is a series circuit.

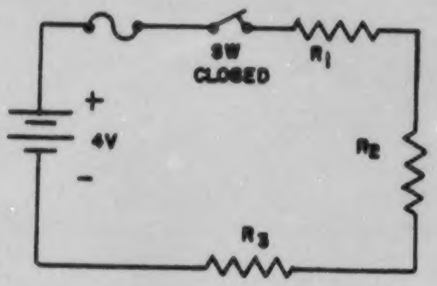
Answer: (✓) 2.

In any practical circuit certain components are necessary. In a series circuit, the required components are a source of voltage, conductors, a fuse or other protective device, a switch for circuit control, and one or more units of resistance. The components must be connected with only one path for current flow.

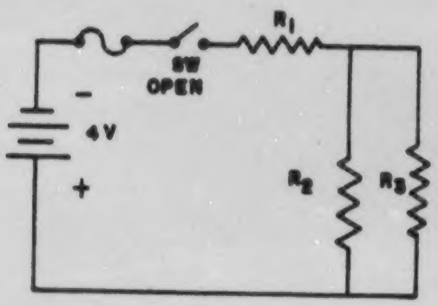
Place a check (✓) by the circuits that are connected in series.


R1
SW
CLOSED
-
4V
I
R2

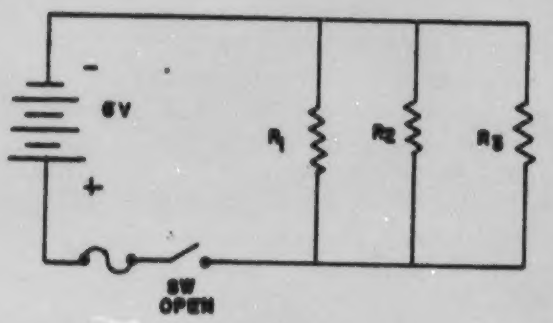
1. ______________


SW
CLOSED
R1
+
4V
-
R2
R3

2. ______________


R1
SW
OPEN
-
4V
+
R2
R3

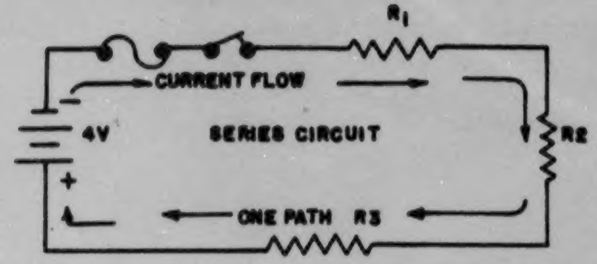
3. ______________


-
6V
+
R1
R2
R3
SW
OPEN

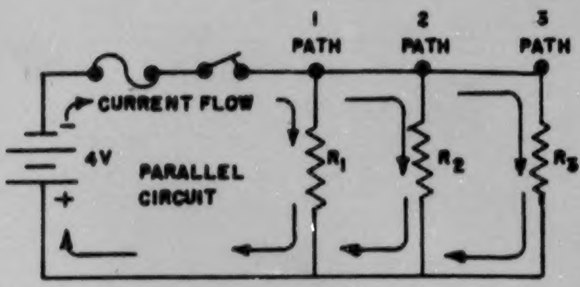
4. ______________

Answer: 1. ✓
2. ✓

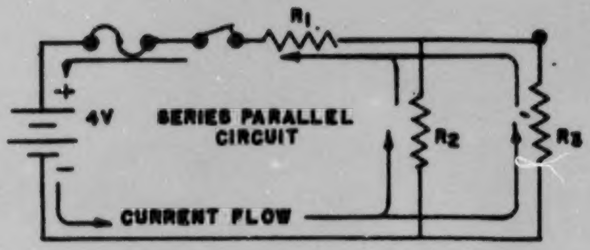
A series circuit is one in which there is only one path through which the voltage can force current.


R1
CURRENT FLOW
−
4V
SERIES CIRCUIT
R2
+
ONE PATH R3

A circuit which has two or more paths through which current can flow is called a parallel circuit.


1 PATH
2 PATH
3 PATH
CURRENT FLOW
−
4V
PARALLEL CIRCUIT
+
R1
R2
R3

A circuit that has two resistors, each with a path for current flow, and one resistor through which all current must flow to return to the voltage source is a series-parallel circuit. As its name implies, and the drawing illustrates, series-parallel circuits are combinations of series and parallel circuits.


R1
+
4V
SERIES PARALLEL CIRCUIT
−
R2
R3
CURRENT FLOW

An electrical circuit that has only one path for current flow is known as a

____ a. parallel circuit.

____ b. parallel-series circuit.

____ c. series-parallel circuit.

____ d. series circuit.

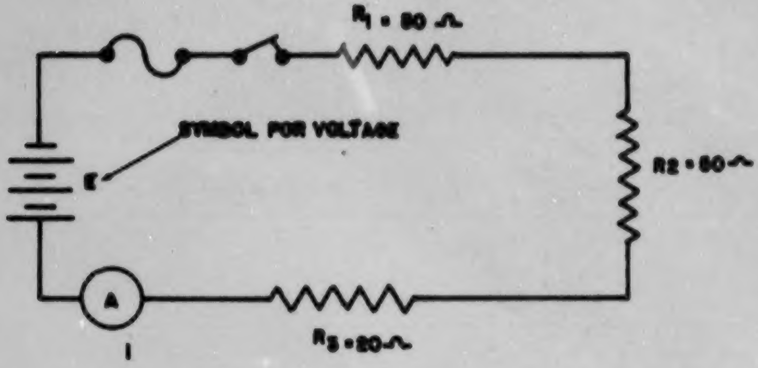
(Check the correct answer)

Answer: ✓ d.

Now that you know the definition of a series circuit, let us discuss its characteristics. First, we will learn the characteristics of resistance. The total resistance is the sum of the individual resistors in the circuit. Thus, a 20-ohm resistor and two 50-ohm resistors connected in series would have a total resistance (R_t) of 120 ohms.

Study the diagram below.

Symbol for Ohms - Ω



$$20\,\Omega + 50\,\Omega + 50\,\Omega = 120\,\Omega$$

OR

$$R_T = 120\,\Omega$$

Place a check (✓) by the statement that describes the characteristics of resistance in a series circuit.

___ 1. The total resistance is equal to the voltage divided by the sum of the individual resistors.

___ 2. The total resistance is equal to the sum of the individual resistors divided by current.

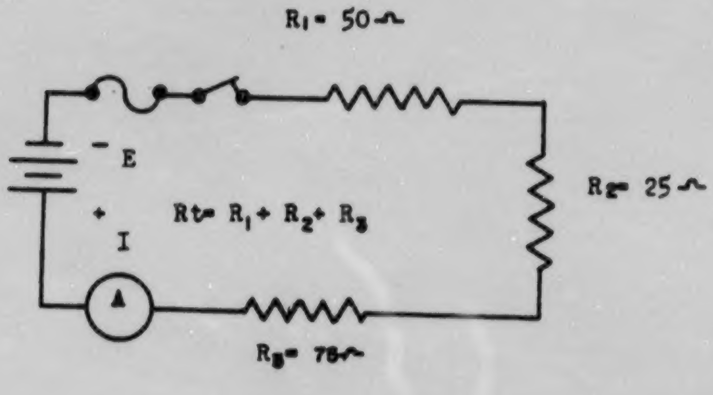
___ 3. The total resistance is the sum of the individual resistors.

Answer: ✓ 3.

The total resistance in a series circuit is equal to the sum of the individual resistors. Written as a formula, we have $R_t = R1 + R2 + R_3$. This formula merely means that to find total resistance of a series circuit, add up all the separate resistances in the circuit. If you had a circuit where the resistance of R_1 was 5 ohms, R_2 was 10 ohms, and R_3 was 15 ohms, the total resistance would be 5 + 10 + 15 = 30 ohms.

The total resistance for a circuit is determined as illustrated in the diagram below.

$R_1 = 50\Omega$
$R_2 = 25\Omega$
$R_3 = 75\Omega$
$Rt = 150\Omega$



Place a check (✓) by the statement that describes a characteristic of a series circuit.

____ 1. The total resistance is equal to the sum of the individual resistors in the circuit.

____ 2. The total resistance is equal to the sum of the resistors divided by the number of resistors in the circuit.

Answer: ✓ 1.

Now, let us make sure we understand the information presented up to this point. If you do not select the correct answers to the following questions, return to Page 2 and review the information. If you select the correct answers turn to Page 8 and continue through the package.

1. A circuit that has resistors connected so that there is only one path for current flow is known as a

____ a. parallel-series circuit.
____ b. parallel circuit.
____ c. series-parallel circuit.
____ d. series circuit.

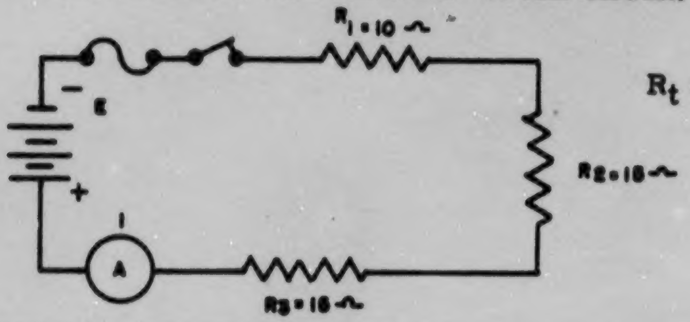
(Check the correct answer)

2. This formula $R_t = R_1 + R_2$ expresses the characteristic of a

____ a. simple circuit.
____ b. parallel circuit.
____ c. series circuit.
____ d. series-parallel circuit.

(Check the correct answer)

3. Determine the total resistance of this circuit.



R_t = ____ Ω

Answers: 1. ✓ d
2. ✓ c
3. R_t = 40 Ω

The next characteristic of a series circuit deals with current. In a series circuit, there is only one path for current flow; when it leaves the voltage source it is forced through each resistor. Therefore, the same amount of current flows in each part of the circuit.

Place a check (✓) by the statement(s) that define(s) the characteristics of a series circuit.

___ 1. The total resistance is equal to the sum of the individual resistors in the circuit.

___ 2. The current will divide equally between the resistors in the circuit.

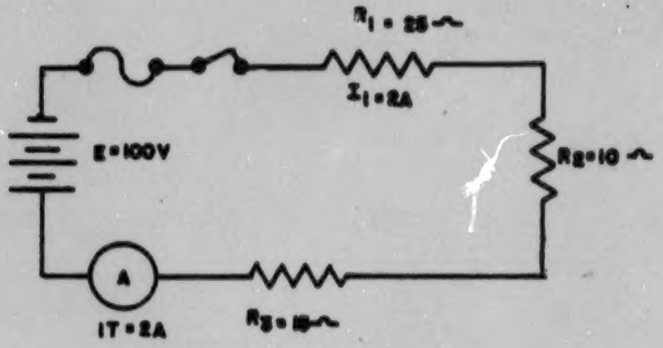
___ 3. The total resistance is equal to the sum of the individual resistors multiplied by the number of resistors.

___ 4. The same amount of current flows through each resistor in the circuit.

Answer: ✓ 1.
✓ 4.

In a series circuit the same amount of current flows in each part of the circuit. This statement means that if you have two amps of current at the first resistor, any other place in the same circuit will have two amps of current. We measure the current with an ammeter. Regardless of where we place the ammeter in the circuit, it will read two amps.

Study the diagram below.



The current through R_1, R_2, and R_3 will be two amps; total current will be two amps.

Place a check (√) by the statement(s) that describe(s) the characteristics of a series circuit.

___ 1. The current flow is equal to the sum of the amps at each resistor.

___ 2. The current is equal to the sum of the amps at each resistor multiplied by the total resistance.

___ 3. The total resistance is equal to the sum of the individual resistors in the circuit.

___ 4. The total resistance is equal to the current times the voltage.

___ 5. The current flow is equal to the resistance times the voltage.

___ 6. The current flow is the same throughout the circuit.

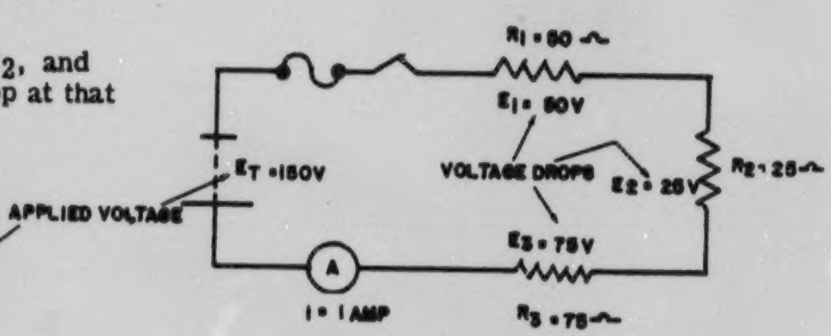
Answer: ✓ 3.
✓ 6.

Opposition to current flow through a resistor causes a voltage drop across the resistor. In other words, each resistor consumes a share of the available voltage. Each resistor, then, uses less than the total voltage applied to the circuit. However, the sum of the voltage drops will equal the applied voltage. The formula for finding applied voltage, then, would be $E_t = E1 + E_2 + E_3$ etc.

Study the diagram below.

The amount at E_1, E_2, and E_3 is the voltage drop at that resistor.

$E_1 = 50V$
$E_2 = 25V$
$E_3 = 75V$
$E_t = 150V$



$R_1 = 50\,\Omega$
$E_1 = 50V$
$E_T = 150V$
APPLIED VOLTAGE
VOLTAGE DROPS
$E_2 = 25V$
$R_2 = 25\,\Omega$
$E_3 = 75V$
A
I = 1 AMP
$R_3 = 75\,\Omega$

Place a check (√) by the true statement.

___ 1. Each resistor will consume the same voltage, regardless of the amount of resistance.

___ 2. The same voltage flows through each unit of resistance.

___ 3. The sum of the voltage drops in a series circuit is equal to the applied voltage.

Answer: √ 3.

You can now see that another characteristic of a series circuit is that the applied voltage is equal to the sum of the voltage drops across all resistors. Or, stated another way, applied voltage will equal the sum of all the separate voltage drops.

Place a check (✓) by the statement(s) that describe(s) the characteristics of a series circuit.

___ 1. The current flow will divide among the resistors according to the amount of resistance.

___ 2. Applied voltage is equal to the sum of the voltage drops across all resistors.

___ 3. Total resistance is equal to the sum of the individual resistors in the circuit.

___ 4. Applied voltage is equal to the current divided by resistance at each resistor.

___ 5. The total resistance in the circuit will be less than the sum of the individual resistors.

___ 6. The current flow is the same throughout the circuit

Answer:
✓ 2.
✓ 3.
✓ 6.

Let's review the information on the definition and characteristics of a series circuit. If you do not select the correct answers to the following question, return to Page 8 and review the information. If you select the correct answers, continue through the package.

Check (√) the statements that define or describe the characteristics of a series circuit.

____ 1. A circuit that has only one path for current flow.

____ 2. A circuit that has more than one path for current flow is a series circuit.

____ 3. The total resistance is equal to the sum of the individual resistors in the circuit.

____ 4. The current flow will divide among each individual resistor.

____ 5. The total resistance will divide equally among the resistors.

____ 6. The current flow is the same throughout the circuit.

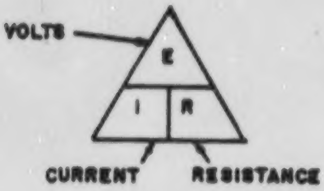
____ 7. Applied voltage is equal to the sum of the voltage drops across all resistors.

____ 8. The voltage drop at each resistor will be the same.

Answer:

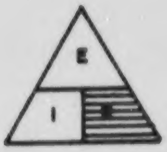
✓ 1.
✓ 3.
✓ 6.
✓ 7.

Now that you know the definition and characteristics of a series circuit, let us briefly review Ohm's Law before proceeding into circuit analysis. We find that current in a circuit is directly proportional to the applied voltage, and inversely proportional to the resistance. Ohm's Law, then, can be stated as a mathematical formula - $I = E/R$, $R = E/I$, and $E = I \times R$. Knowing any two of the quantities in the formula (I, R, or E), the third quantity can be calculated. Example: Given $E = 10V$ and $R = 5\Omega$, we can find I by using $I = E/R$. $I = \frac{10V}{5} = 2A$. The Ohm's Law triangle will help you remember the formula.



The formula for finding the unknown quantity or value will be given by covering the unknown factor of the triangle and performing the simple mathematical problem left showing.

Example: Given $E = 70V$ and $I = 7A$, solve for R.

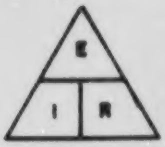


In the triangle you cover the "R," which tells you to divide the value of I into the value of E. Then $R = \frac{70V}{7A} = 10\ \Omega$.

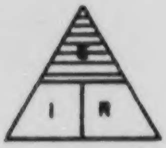
Solve the problem below, and mark through the letter in the triangle that gives you the correct formula.

$I = 2A$

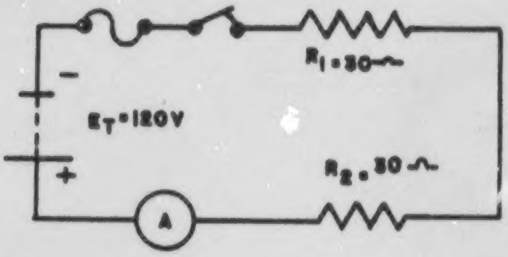
$R = 15\Omega$



Answer: 30V



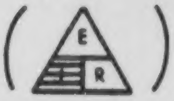
We use Ohm's law to determine the total value of current, voltage, or resistance of a circuit. We also use Ohm's law to determine the value of current, voltage, or resistance at each resistor. Let us analyze a circuit that has a 120 volt source and two 30 ohm resistors in series.


$R_1 = 30\Omega$
−
$E_T = 120V$
+
$R_2 = 30\Omega$
A

In this case, we know the total voltage is 120V. We add the value of the individual resistors (30Ω + 30Ω = 60Ω) to determine the total resistance.

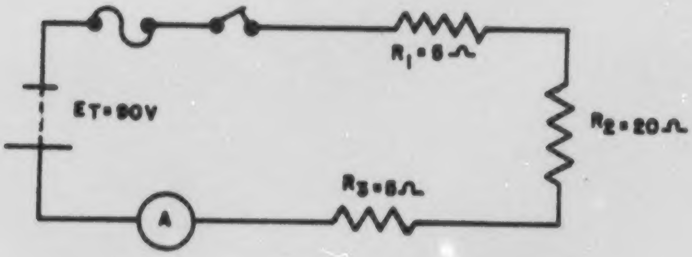
Now we have two of the total values: 120V and 60Ω. We use I = E/R

I = ______ A



to determine the current - $\frac{120V}{60\Omega} = 2A$.

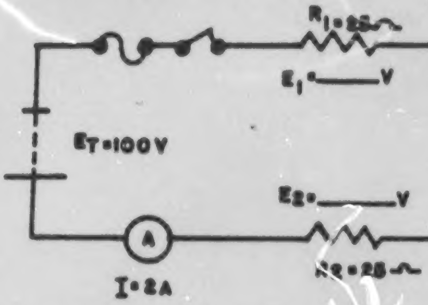
Now you try one. What is the total current flow in the following circuit?


$R_1 = 5\Omega$
$E_T = 90V$
$R_2 = 20\Omega$
$R_3 = 5\Omega$
A

I = ______

Answer: 3A

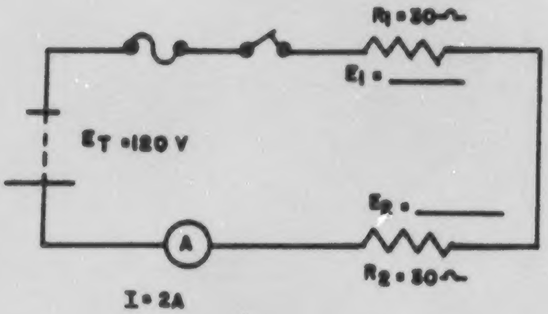
Now we will determine the voltage values (voltage drop) at individual resistors and the total circuit values (applied voltage). To determine the voltage drop at a resistor, we must know the amount of resistance in the resistor and the current flow through the resistor.



In this circuit, we know the amount of resistance at R_1 (25Ω), and the current through R_1 (2A). The voltage drop at R_1 would equal 25Ω x 2A.

The voltage drop at R_1 would be 50V.
The voltage drop at R_2 would be 50V.

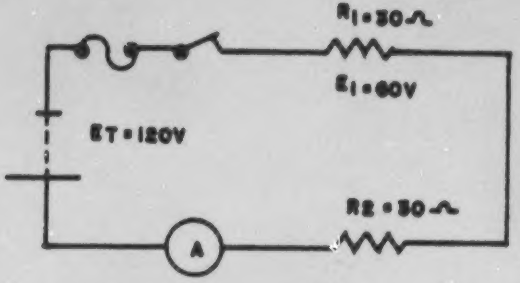
Determine the voltage drop at each resistor in the circuit below.



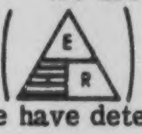
2F-76-663

Answer: R_1 = 60V; R_2 = 60V.

When we determine the current through an individual resistor, we must also know two of the three values at the resistor.


R1=30Ω
E1=60V
ET=120V
R2=30Ω
A

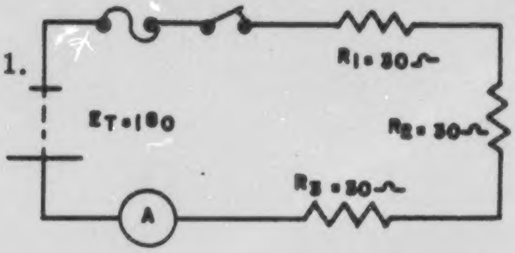
I = ____ A

We know two values at R_1 – 60V and 30 Ω. We use the formula I = E/R () $\frac{60V}{30\Omega} = 2A.$ We have determined the current flow through R_1.

Since the current is the same throughout the circuit, all we must do is determine the current at one point to know the total current in the circuit. Therefore, the total current through the circuit above is 2A.

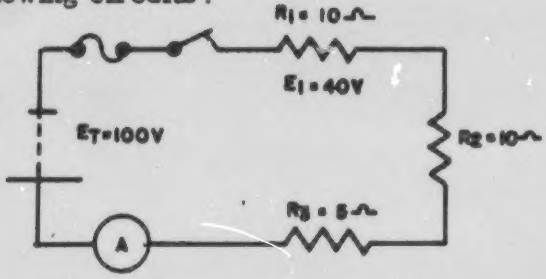
What is the total current flow in the following circuits?

1.


R1=30Ω
ET=180
R2=30Ω
R3=30Ω
A

I = ____

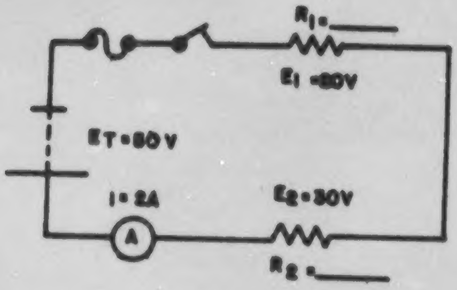
2.


R1=10Ω
E1=40V
ET=100V
R2=10Ω
R3=5Ω
A

I = ____

Answer: 1. 2A
2. 4A

Now, let us determine the resistance of an individual resistor, and the total resistance of a circuit. When Ohm's law is applied to an individual resistor, we must know the voltage drop at the resistor, and the current flow through the resistor.

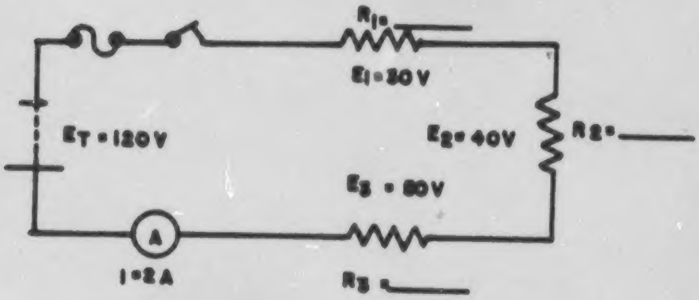


To determine the ohms at R_1, we divide the amount of voltage drop (20V) by the amount of current (2A). The formula is $R = E/I = \frac{20V}{2A} = 10\Omega$

The resistance at R_2 is 15Ω

If we know the resistance at each resistor, we add these values to obtain the total resistance in the circuit.

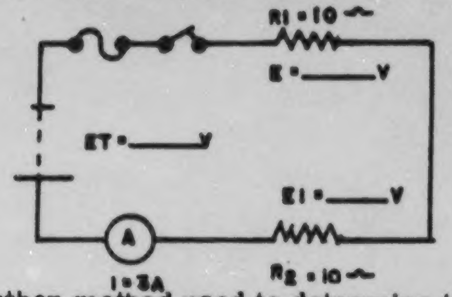
Determine the total resistance in the circuit below.



R_t = ______

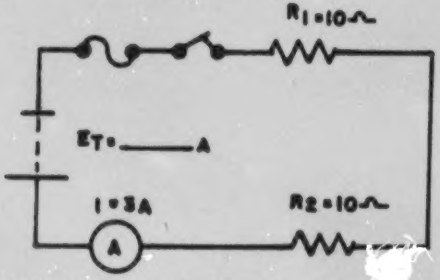
Answer: 60Ω

As you know, the total voltage of a series circuit is equal to the sum of the voltage drops in the circuit. Therefore, if we determine the voltage drop at each resistor, and add these values, we know the applied voltage.



First we determine the voltage drop at R_1. 10Ω x 3A = 30V. Then we determine the voltage drop at R_2. 10Ω x 3A = 30V.
E_t = 30V + 30V = 60V.

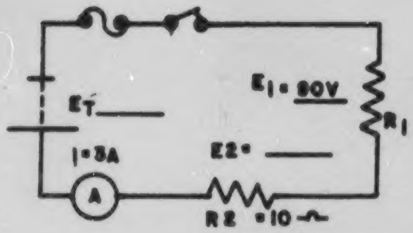
Another method used to determine the total voltage is through the use of Ohm's Law. We must know the total resistance and the current flow through the circuit. When we know the two values (resistance and current) we use the following equation: E = I x R.



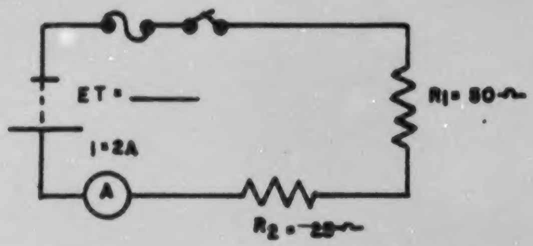
First we must find total resistance
R_t = 10Ω + 10Ω = 20Ω.
Now, we multiply the total resistance (20Ω) by the current (3A).
E_t = 3A x 20Ω = 60V.

Determine the applied voltage of the circuits below.

1.

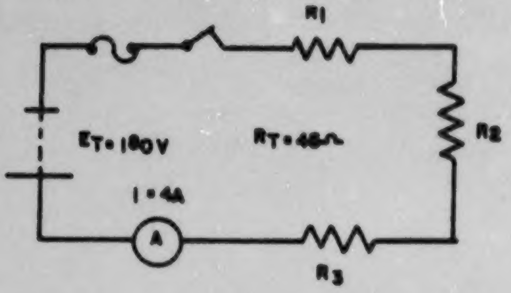


2.



Answer:
1. 120V
2. 150V

To determine the total resistance of a circuit, we must know the applied voltage and the current flow in the circuit. If we know the two values (applied voltage and current), we divide the current into the voltage to find the total resistance. Use the equation: $R = E/_I$.

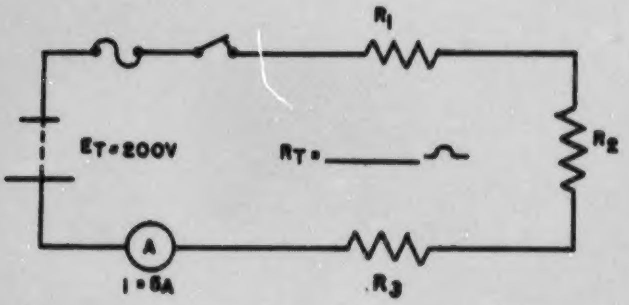


If we know the applied voltage and the current, we divide the current into the voltage to determine total resistance.

$$\frac{180V}{4A} = 45\Omega$$

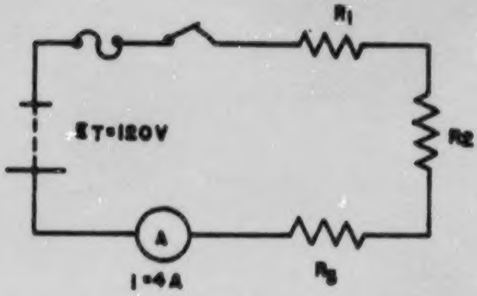
Notice that we do not determine the resistance of each resistor.

Determine the total resistance in the circuit below.



Answer: 40Ω

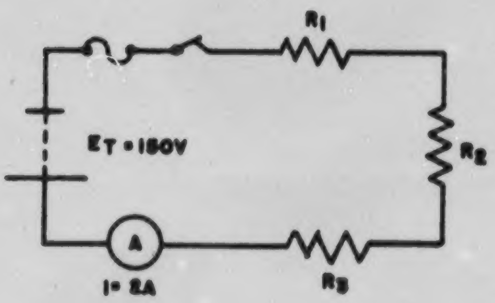
At this point, we know how to determine the total voltage, current, and resistance of a circuit; we also know how to determine the values of individual resistors. Now, we will determine the power expended in a circuit or resistor. When voltage causes current flow in a circuit, work is done. The rate at which this work is done is called the power rate, and it is measured in watts. The symbol P indicates electrical power. It is equal to the voltage across a circuit multiplied by the current through the circuit. Thus, the basic power formula is P = I x E.



In this circuit, we have the required values (total voltage and current) necessary to determine the Power.

P = I x E = 4A x 120V = 480 Watts

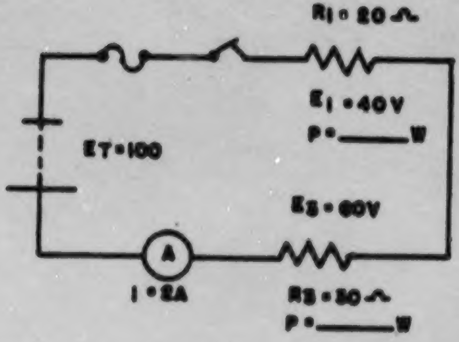
Determine the power consumed in the circuit below.



P = ________

Answer: 300 W

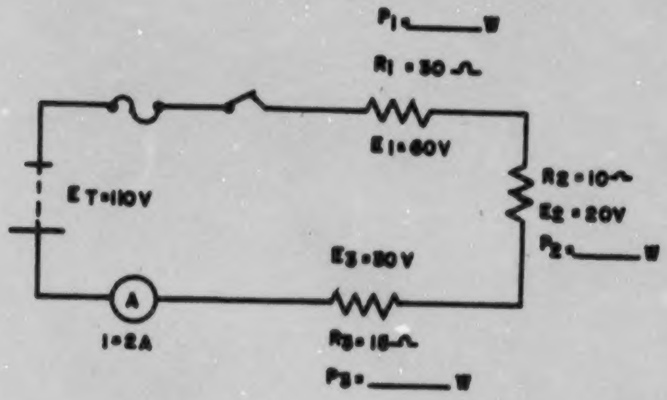
To determine the power consumed at an individual resistor, we must know the amount of voltage drop and the amount of current at the resistor. Remember, you multiply the current times the voltage to determine the power. P = current x voltage.


R1 = 20Ω
E1 = 40V
P = ____W
ET = 100
E3 = 60V
A
I = 2A
R3 = 30Ω
P = ____W

To determine the power at R_1, we would multiply the amps times voltage.
$P = I \times E = 2A \times 40V = 80W$.

Power at R_3 would be 120W.

Determine the power consumed at each resistor in the circuit below.

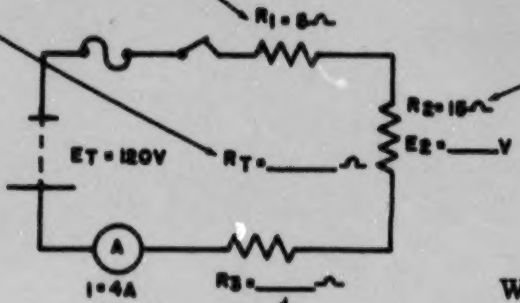

P1 = ____W
R1 = 30Ω
E1 = 60V
R2 = 10Ω
E2 = 20V
P2 = ____W
ET = 110V
E3 = 30V
A
I = 2A
R3 = 15Ω
P3 = ____W

Answer: P_1 = 120W; P_2 = 40W; P_3 = 60W.

Now, let us analyze a circuit and utilize some of the information just covered. In the circuit below, we must determine total resistance, voltage drop at R_2, and the resistance at R_3.

First, we determine the voltage drop at R_1.
$E = I \times R = 4A \times 5\Omega = 20v$

$5\Omega + 15\Omega + 10\Omega + 30\Omega$



Next we determine the voltage drop at R_2
$4A \times 15\Omega = 60v$

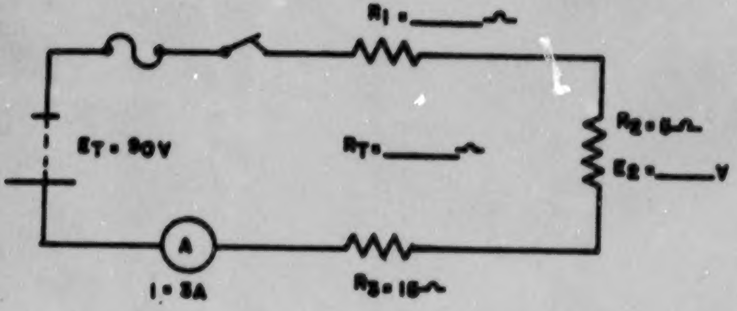
We now add the two values ($20v + 60v = 80v$) and subtract this value ($80v$) from the applied voltage which gives us the voltage drop at R_3.

$120v\ (E_t) - 80v = 40v$

We divide 4A into 40 volts to obtain the resistance at R_3.

$$\frac{40v}{4A} = 10\Omega$$

Determine the unknown values in the circuit below.


R_1 = ____ Ω
E_T = 90V
R_T = ____ Ω
R_2 = 5Ω
E_2 = ____ V
A
I = 3A
R_3 = 15Ω

Answer: $R_1 = 10\,\Omega$; $E_2 = 15V$; $R_t = 30\,\Omega$

When analyzing a circuit, make use of the known values, and remember the formulas:

$R = E/_I$, $I = E/_R$, $E = I \times R$, and $P = I \times E$.

1. The two known values in this case are at R_1. We divide the 10Ω into the 30V to determine the current in the circuit.

$$\frac{30V}{10\Omega} = 3A$$

2. Now, we know two values at R_2 - Current and Resistance.

$3A \times 5\Omega = 15V$

3. We also know two values at R_3 - Current and Voltage.

$$\frac{45V}{3A} = 15\Omega$$

4. To determine power at 2 Resistor, we multiply the current times the voltage at that resistor.

$3A \times 45V = 135W$

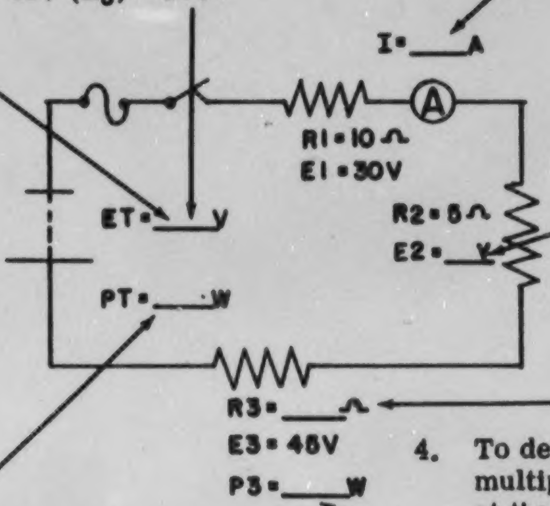
5. $30V (E_1) + 15V (E_2) + 45V (E_3) = 90V$

or

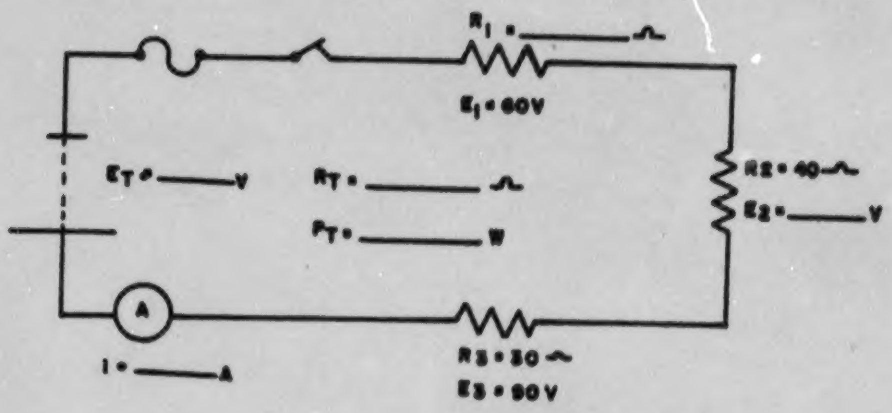
$30\Omega (R_t) \times 3A = 90V$

6. We multiply the current times the total voltage to determine the total power.

$3A \times 90V = 270W$



Determine the unknown values in the circuit below.


R_1 = ______ Ω
E_1 = 60V
E_T = ______V
R_T = ______ Ω
P_T = ______ W
R2 = 40 Ω
E2 = ______ V
A
I = ______ A
R3 = 30 Ω
E3 = 90 V

Answer: I = 3A; E_2 = 120V; E_t = 270V; R_1 = 20Ω ; R_t = 90Ω ;
P_t = 810W

CRITERION EXAMINATION

(You must answer correctly 14 out of 15 items to satisfactorily complete this unit)

1. An electrical circuit that has only one path for current flow is known as a

___ a. parallel circuit.

___ b. parallel-series circuit.

___ c. series circuit.

___ d. series-parallel circuit.

2. Place an "S" by each statement that describes the characteristics of a series circuit.

___ a. A circuit containing two or more units of resistance, each having a separate path of current flow.

___ b. Total resistance is equal to the sum of the individual resistors in the circuit.

___ c. The current flow is the same throughout the circuit.

___ d. The same voltage value is applied to each unit of resistance.

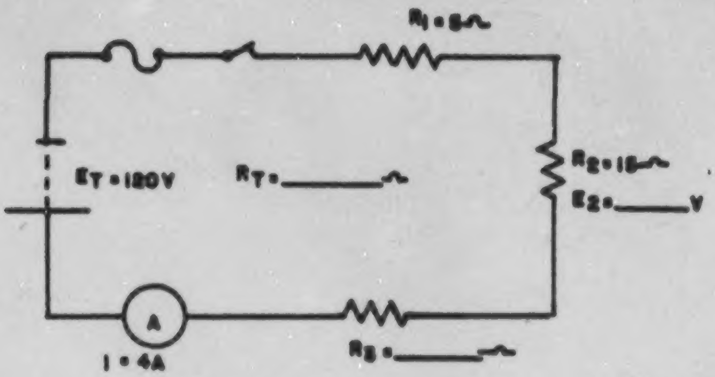
___ e. Has only one path for current flow.

___ f. Total current divides among resistors in proportion to their resistance.

___ g. Total resistance is less than that of any single resistor.

___ h. Applied voltage is equal to the sum of the voltage drops across all resistors.

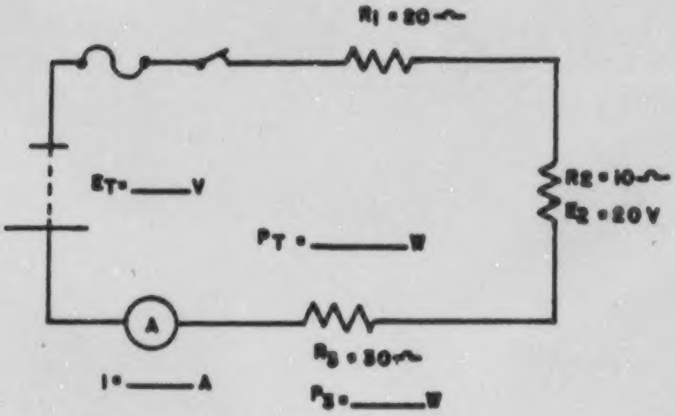
3. **Determine the unknown values in each of the following circuits.**


R_1 = 5 Ω
E_T = 120 V
R_T = ______ Ω
R_2 = 15 Ω
E_2 = ______ V
A
I = 4A
R_3 = ______ Ω

E_2 = ____ V

R_3 = ____ Ω

R_t = ____ Ω

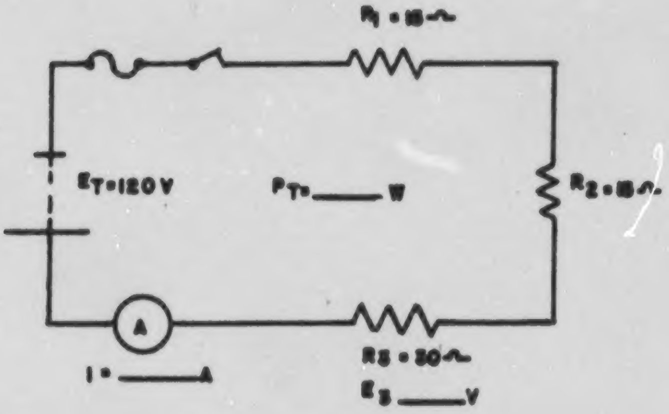

R_1 = 20 Ω
E_T = ______ V
R_2 = 10 Ω
E_2 = 20 V
P_T = ______ W
A
I = ______ A
R_3 = 30 Ω
P_3 = ______ W

E_t = ____ V

I = ____ A

P_3 = ____ W

P_t = ____ W


R_1 = 15 Ω
E_T = 120 V
P_T = ______ W
R_2 = 15 Ω
A
I = ______ A
R_3 = 30 Ω
E_3 ______ V

I = ____ A

E_3 = ____ V

P_t = ____ W

2TPT-3101-09

Technical Training

DEPARTMENT OF CIVIL ENGINEERING TRAINING

Parallel DC Circuits

May 1968

11-6

Designed For ATC Course Use

VALIDATION DATA

This programmed text on Parallel DC Circuits has been validated on 39 students. Target population consisted of 39 students enrolled in ABR 54330, Electrical Power Production Course.

The Criterion Examination has a total of 29 responses, with 26 out of 29 being the standard of performance. Any 26 correct responses is 100%.

The following results indicate time taken to complete the program and scores obtained on the Criterion Examination.

	RANGE	AVERAGE
Time	42 - 160 Min	105 Min
Scores	50 - 100%	92.1%

OBJECTIVES

After completing this unit of instruction, you should be able to accomplish the following:

- Identify the definition of a parallel circuit.
- Identify the characteristics of a parallel circuit.
- Identify the various arrangements of parallel circuits from an illustration containing circuit schematics.
- Solve for unknown values of current, voltage, resistance, and power using electrical formulas and circuit characteristics when given parallel circuit schematics and sufficient known values.

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Follow These Steps:

1. As you study the text, you are required to solve problems, complete information, and circle or check items from a group.

2. Questions and answers are separated. Use a 5 x 7 card, or heavy paper you can't see through, as a marker. Slide the card down until you expose the divider.

You now have one problem exposed.

3. Read the information given and work the problem. Write your answer in the space provided.

4. After you have made your response, slide the marker further down the paper and compare your answer with the correct answer.

   a. If your answer is right, continue working the problems.

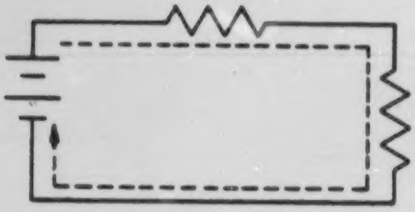
   b. If your answer is wrong, restudy the information and work the problem again.

Then proceed to the next problem.

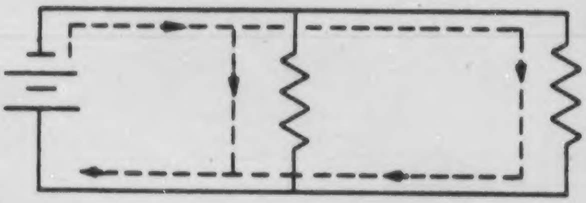
At Christmas time when you have finally decided to check the lights for the tree, you may have noted that there were two different types. One set of lights was a particular problem because, as one of its lights burned out, all of its lights would go out. This was a series-connected circuit. The set of lights that suited your purpose best was connected in parallel. In working on this set you found that when one light went out, the others still continued to glow.

1. A parallel circuit is a circuit containing two or more units of resistance, each unit having a separate path of current flow.

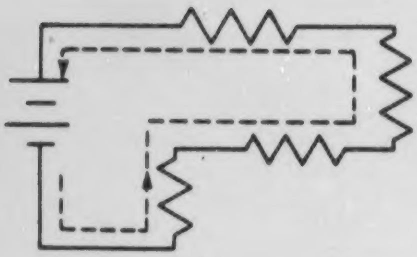
   From the circuits shown below, select those that are parallel by drawing a circle around its corresponding letter.



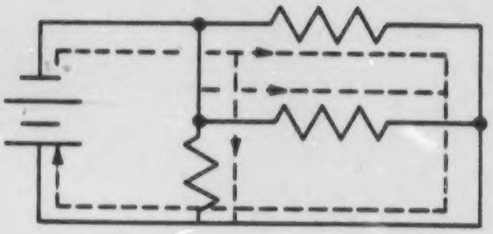
a.



b.



c.



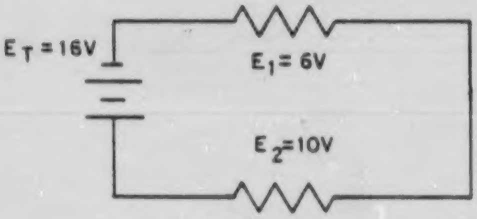
d.

---

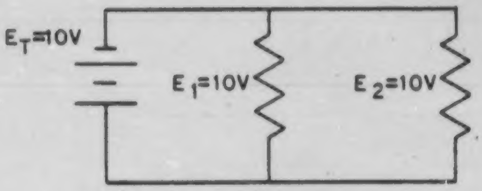
b d

One characteristic of a parallel circuit is that the same voltage is applied to each unit of resistance. The formula which gives this relationship is $E_t = E_1 = E_2 = E_3$.

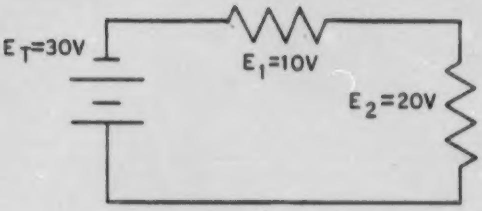
2. Which of the circuits below demonstrates the voltage characteristic of a parallel circuit? (Circle the letter of your answer.)


E T = 16V
E1 = 6V
E2 = 10V

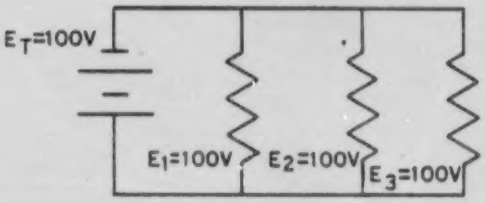
a.


ET = 10V
E1 = 10V
E2 = 10V

b.


ET = 30V
E1 = 10V
E2 = 20V

c.


ET = 100V
E1 = 100V
E2 = 100V
E3 = 100V

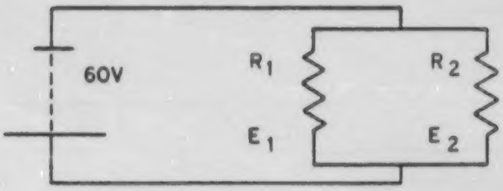
d.

---

b d

3. Find the unknown voltages for the circuits below:

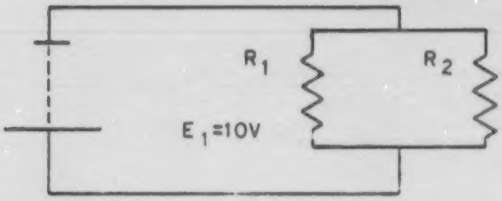
a.


60V
R1
E1
R2
E2

E_1 = ____ V

E_2 = ____ V

b.



E_t = ____ V

E_2 = ____ V

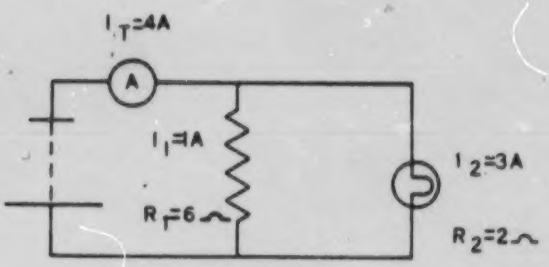
---

a. 60 V
60 V

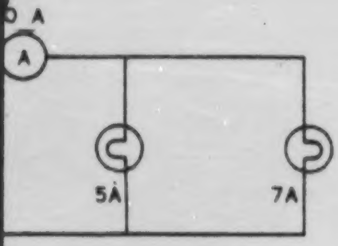
b. 10 V
10

other characteristic of a parallel circuit is that total current is equal to the
ı of the currents through all the paths. This is expressed in formula form $I_t = I_1 + I_2 + I_3$. Total current divides among the resistors inversely proportional to their resistance.

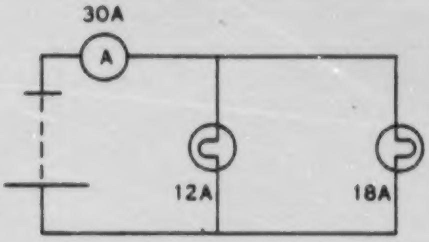
the circuit below, notice that the sum of the currents in the branches equals total current. It's also important to see the resistance current relation-p. R_1, which is three times larger than R2, has one third the amount of rrent flowing through it as R_2.



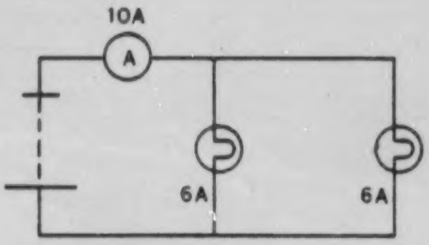
Select the circuit below which demonstrates the current characteristic of a parallel circuit. (Circle the letter of your answer.)



a.



b.

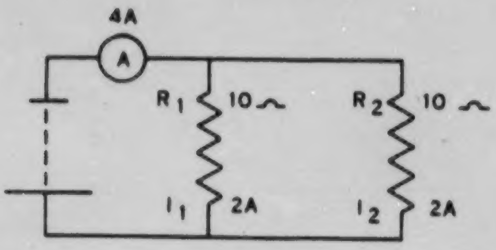


c.

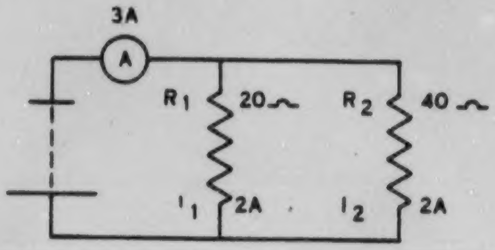
---

b

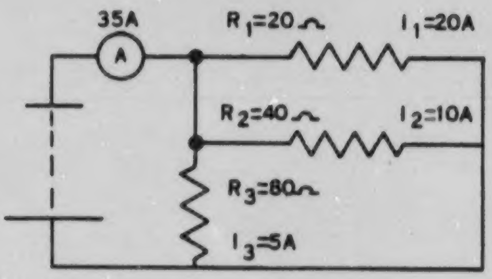
5. Which of the circuits below demonstrate the correct current division in a parallel circuit? (Circle the letter of your answer.)


4A
A
R1
10 Ω
R2
10 Ω
I1
2A
I2
2A

a.


3A
A
R1
20 Ω
R2
40 Ω
I1
2A
I2
2A

b.


35A
A
R1=20 Ω
I1=20A
R2=40 Ω
I2=10A
R3=80 Ω
I3=5A

c.

---

a. c.

6. Complete the statements below:

a. A parallel circuit contains __________ or __________ units of resistance, each having a __________ path for current flow.

---

two more separate

b. The voltage applied to each resistor in a parallel circuit is the __________ as the total or applied voltage.

---

same

c. Total current in a parallel circuit is the ____________ of the current through the individual resistors.

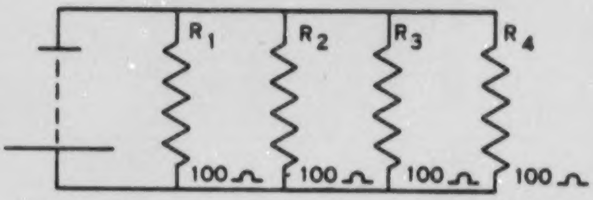
sum

d. Current in a specific resistor of a parallel circuit will be ________________ proportional to its resistance.

inversely

Total resistance in a parallel circuit is always less than the smallest valued resistor in the circuit. When the resistor values are equal we can find R_t by dividing the value of one resistor by the number of resistors in parallel.

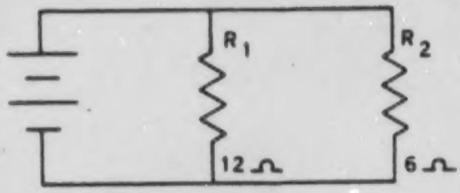
Example:



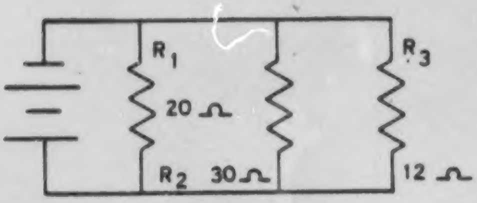
In the above circuit the total resistance would have to be less than 100 the smallest valued resistor in the circuit. The four resistor values are equal so we can divide the value of one resistor (100Ω) by the number of resistors having that value (4).

$$R_t = \frac{100}{4} = 25\Omega$$

7.



a.


R1
20 Ω
R2 30 Ω
R3
12 Ω

b.

In Circuit a. the total resistance would have to be less than ____________.

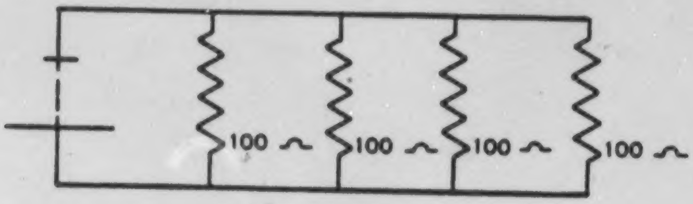
6

In Circuit b. the total resistance would have to be less than ____________

12

8. **Solve the circuits below for R_t.**

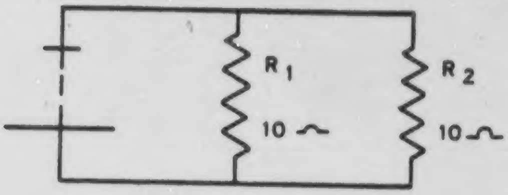
a.


100 Ω
100 Ω
100 Ω
100 Ω

R_t = ______ Ω

25 Ω

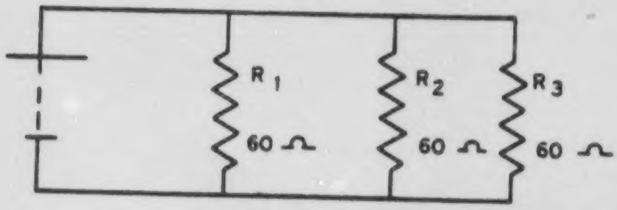
b.


R 1
10 Ω
R 2
10 Ω

R_t = ______ Ω

5 Ω

c.


R 1
60 Ω
R 2
60 Ω
R 3
60 Ω

R_t = ______ Ω

20 Ω

9. Identify the characteristics of a series and parallel circuit by placing an "S" by each series characteristic and a "P" by each parallel characteristic.

____ a. Has only one path for current flow.

____ b. Total current divides among the resistors inversely proportional to their resistance.

____ c. Total resistance is always less than the smallest valued resistor.

____ d. Same voltage value is applied to each unit of resistance.

____ e. Current flow is same throughout circuit.

____ f. Total resistance is equal to sum of individual resistors.

____ g. Circuit containing two or more units of resistance, each having a separate path of current flow.

____ h. Applied voltage is equal to the sum of the voltage drops across all resistors.

---

a. S c. P e. S g. P
b. P d. P f. S h. S

When answering the next several questions, you'll find the answers in the left margin and just below the questioning area.

Let's review reciprocals and the addition of fractions as they are important to our knowledge of parallel circuits.

The reciprocal of the number 8 is 1/8, of 100 is 1/100.
The reciprocal of 1/50 is 50, of 1/35 is 35.

10. Find the reciprocals of the numbers below.

80, 20, 45, 1/6, 1/130, 1/1000

0, 1/20,

5, 6, 130

0

Now let's add the reciprocals of the following numbers.

20, 30, 60

We would add these values this way: 1/20 + 1/30 + 1/60.
To add fractions we first must find the least common denominator. (The lowest value 20, 30 & 60 will divide into).In this case it is 60.

We now have $\frac{60}{20}$, $\frac{60}{30}$, $\frac{60}{60}$ or $\frac{3 + 2 + 1}{60}$.

This gives us $\frac{6}{60}$ or $\frac{1}{10}$.

11. Add the reciprocal values of the following numbers.

6, 12, and 4

The above problem could have been worked in this way.

① $\frac{1}{6} + \frac{1}{12} + \frac{1}{4}$ least common denominator 12

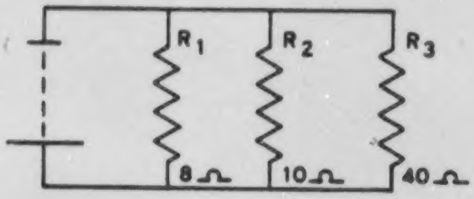
② $\frac{2 + 1 + 3}{12} = \frac{6}{12}$ or $\frac{1}{2}$

One of the methods used to find total resistance of a parallel circuit is by use of the Reciprocal formula.

$$R_t = \frac{1}{1/R_1 + 1/R_2 + 1/R_3}$$

In using the formula we substitute the numerical resistance value into the formula.

Below is an example of using the reciprocal formula to find total resistance.



Steps:

A. The formula for finding total resistance is $R_t = \dfrac{1}{1/R_1 + 1/R_2 + 1/R_3}$

B. Substituting the values in the problem gives us $R_t = \dfrac{1}{1/8 + 1/10 + 1/40}$

C. The least common denominator must be found. It would equal 40.

D. Next you must change all denominators to 40. The formula would then look like this: $R_t = \dfrac{1}{5/40 + 4/40 + 1/40}$

E. Next, add the denominator: $R_t = \dfrac{1}{10/40}$

F. You now have the problem in solvable, workable terms. Your next step is to begin to perform the division:

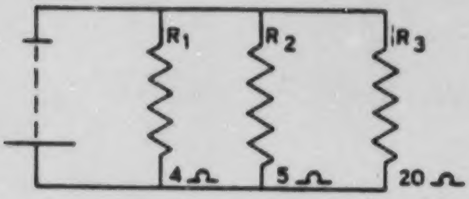
$$R_t = 1/1 \div 10/40$$

G. Using the rule for division of fractions, you invert the fraction and multiply. This gives you

$$R_t = 1/1 \times 40/10$$

H. Then - $R_t = 40/10$ or $\underline{\underline{4}}\ \Omega$.

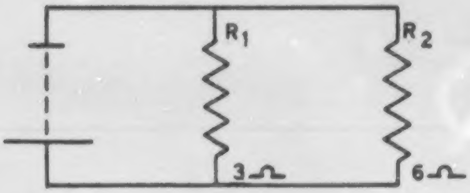
12. Complete the formula below for the given circuit.



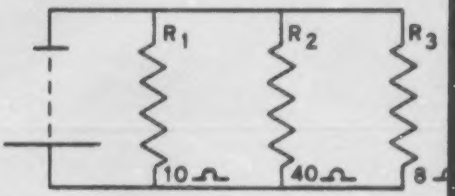
$$R_t = \frac{1}{1/\_\_ + 1/\_\_ + 1/\_\_}$$

$\frac{1}{1/4 + 1/5 + 1/20}$	a. Now the least common denominator must be found. It would equal ________?
20	b. This means we have $R_t = \frac{1}{\_/20 + 4/20 + 1/20}$
5	c. Then $R_t = \frac{1}{\_/20}$
10	d. Then $R_t = 1/1 \div \_/\_$
10/20	e. Then $R_t = 1/1 \times \_/\_$
20/10	f. Then $R_t = 20/10 =$ ________ Ω
2 Ω	

13. Now see how well you can do on these two problems.



a.



b.

---

a. 2Ω

b. 4Ω

The solutions to the above problems are:

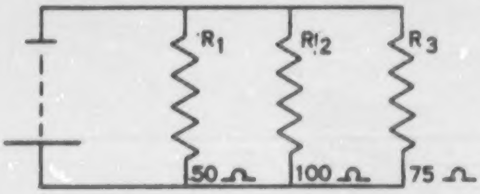
a. 1. $\frac{1}{R_t} = \frac{1}{3} + \frac{1}{6}$ 2. $\frac{1}{R_t} = \frac{2+1}{6} = \frac{3}{6} = \frac{1}{2}$ $R_t = 2$

b. 1. $\frac{1}{R_t} = \frac{1}{10} + \frac{1}{40} + \frac{1}{8}$ 2. $\frac{1}{R_t} = \frac{4+1+5}{40} = \frac{10}{40} = \frac{1}{4}$ $R_t =$

Let's go over some short cuts that may help you.

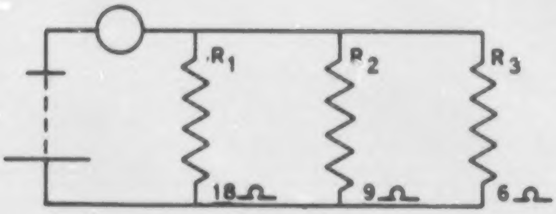
Remember total resistance of a parallel circuit is always less than that of the smallest valued resistor.

Example:



In the above circuit the total resistance would have to be less than 50Ω

14. Select the only possible total resistance for the circuit below. (Circle the letter of your choice.)

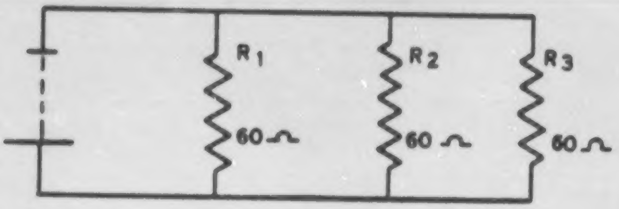


a. 3Ω
b. 6Ω
c. 18Ω
d. 33Ω

3Ω

When the parallel resistors are all of equal size then you can find total resistance by dividing the value of one of the parallel resistors by the number of equal sized resistors.

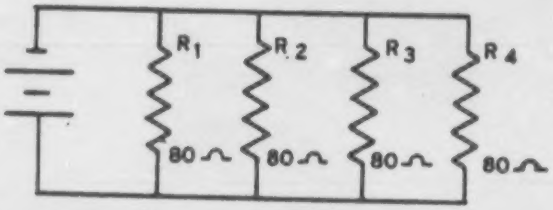
Example:



$R_t = \frac{60}{3}$ size of equal resistor / number of equal resistors

$R_t = 20\,\Omega$

15. Find the total resistance of the circuit below:



$R_t =$ ______ Ω

20

Now let's review the key points.

a. A parallel circuit is a circuit containing ________ or ____________ units of resistance, each having a ______________ path of current flow.

two more separate

b. The same voltage is applied to __________ unit of resistance in a parallel circuit.

---

each

c. Total current in a parallel circuit __________ among resistors __________ proportional to the value of the resistors.

---

divides inversely

d. Total resistance in a parallel circuit can be found by the formula.

$$R_t = \frac{1}{1/\quad + 1/\quad + 1/\quad}$$

$$R_t = \frac{1}{1/R_1 + 1/R_2 + 1/R_3}$$

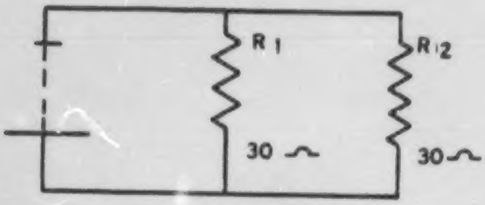
e. Total resistance in a parallel circuit is always less than the __________ valued resistor.

---

smallest

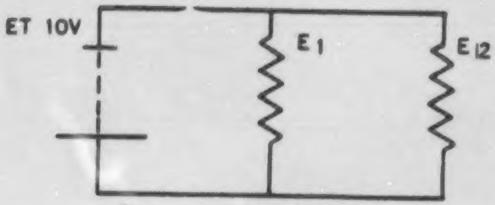
17. To continue our review, solve the circuits below:

a.


R1
R2
30 Ω
30 Ω

RT = _______ Ω

b.



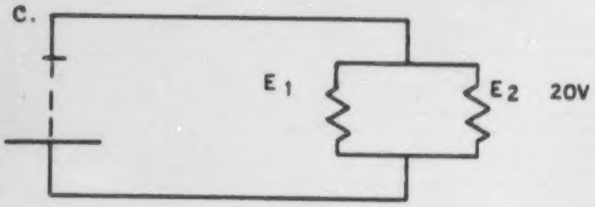
E1 _______ V. E2 = _______ V

---

a. 15 Ω

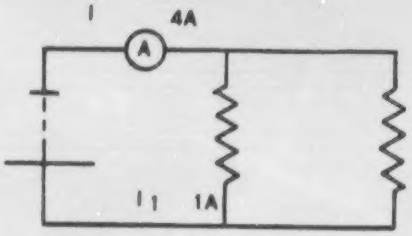
b. 10V, 10V

c.



ET ____ V E1 = ____ V E2 = 20V

d.



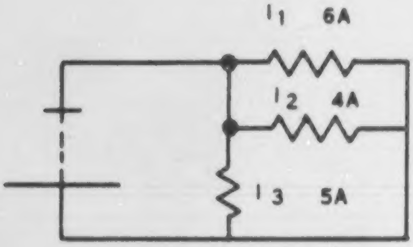
I2 _______ A

---

c. 20V, 20V

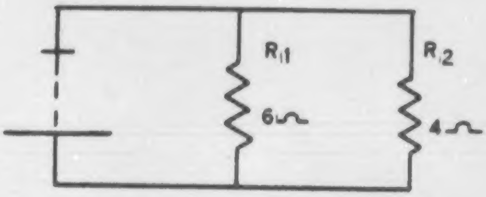
d. 3A

e.


I1 6A
I2 4A
I3 5A

IT = _______ A

f.



RT = _______ Ω

---

e. 15A

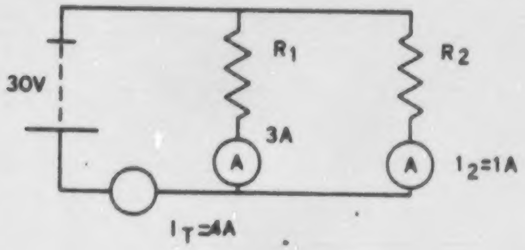
f. 2.4 Ω

The total power (P_t) dissipated in a parallel DC circuit is equal to the applied voltage times the total current. $P_t = E_t \times I_t$.

The power dissipated by each individual resistor in a DC parallel circuit is found by multiplying the voltage applied to it by the current through it.

$$P_1 = E_1 \times I_1 \qquad P_2 = E_2 \times I_2$$

19. In the circuit below find P_t, P_1, and P_2.

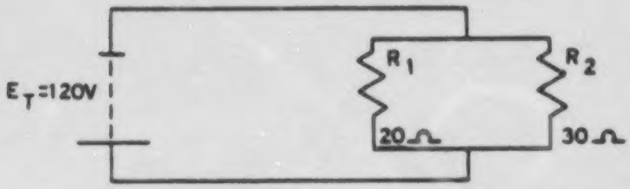


P_t = ____W, P_1 = ____W, P_2 = ____W

120 W, 90 W, 30 W

solving parallel circuit problems we must keep not only the parallel cuit characteristics in mind, but should be ready to make use of Ohm's w.

$$E = I \times R, \quad I = \frac{E}{R}, \quad R = \frac{E}{I}$$



ı will be asked to find values as those which follow:

E_1 = ___ V I_1 = ___ A R_t = ___ Ω P_t = ___ W

E_2 = ___ V I_2 = ___ A P_1 = ___ W

I_t = ___ A P_2 = ___ W

ere are several methods of attacking this problem. Here is one example:

$E_1 = E_2$ will equal 120V as shown by voltage characteristic.

$I_1 = \frac{120V}{20\,\Omega} = 6A$, $I_2 = \frac{120V}{30\,\Omega} = 4A$ obtained through use of Ohm's Law.

I_t = 6A + 4A = 10A as shown by current characteristic. It could also have been determined by Ohm's Law if R_t has been found earlier.

$R_t = \frac{120V}{10A} = 12\,\Omega$ obtained through use of Ohm's Law. R_t also can be found by use of the reciprocal formula.

$t = \frac{1}{1/20 + 1/30} = \frac{5}{60}$ or 12 Ω

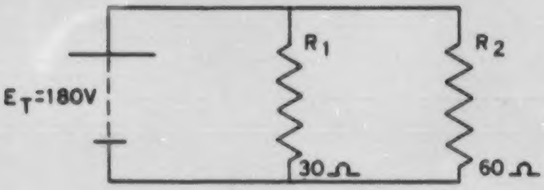
P_t = remember power equal current times voltage.

P_t = 10A x 120V = 1200W using the power formula $P_t = E_t \times I_t$

$P_1 = E_1 \times I_1$ or 120V x 6A = 720W

$P_2 = E_2 \times I_2$ or 120V x 4A = 480W

19. Solve the circuit below.


$E_T = 180V$
R_1
R_2
30Ω
60Ω

E_1 = ____ V
E_2 = ____ V

I_1 = ____ A
I_2 = ____ A
I_t = ____ A

R_t = ____ Ω

P_t = ____ W
P_1 = ____ W
P_2 = ____ W

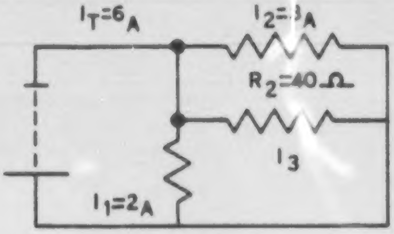
E_1 = 180 V
E_2 = 180 V

I_1 = 6 A
I_2 = 3 A
I_t = 9 A

R_t = 20 Ω

P_t = 1620 W
P_1 = 1080 W
P_2 = 540 W

A parallel circuit with additional branches is similar in solving.


$I_T = 6_A$
$I_2 = 3_A$
$R_2 = 40\Omega$
I_3
$I_1 = 2_A$

You may have to find values as these.

E_1 = ____ V
E_2 = ____ V
E_3 = ____ V
E_t = ____ V

I_t = 6 A
I_1 = 2 A
I_2 = 3 A
I_3 = ____ A

R_t ____ Ω

P_t = ____ W
P_1 = ____ W
P_2 = ____ W
P_3 = ____ W

One approach to this problem is:

A. E_2 = 3A x 40Ω = 120V using Ohm's Law.

B. Et, E_1, E_3 = 120V applying the voltage characteristic.

C. I_t = 6A, I_1 = 2A, I_2 = 3A values given.

D. I_3 = 6A — (2A + 3A) = 1A applying the current characteristic.

E. Rt = $\frac{120V}{6A}$ = 20Ω using Ohm's Law.

F. P_t = 120V (E_t) x 6A (I_t) = 720 W.

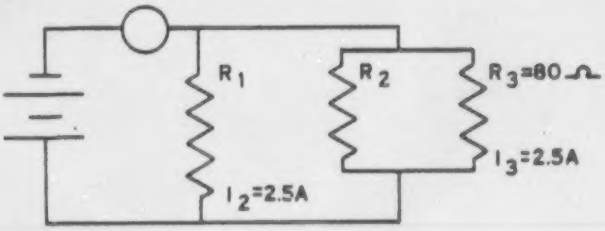
P_1 = 120V (E_1) x 2A (I_1) = 240 W.

P_2 = 120V (E_2) x 3A (I_2) = 360 W.

P_3 = 120V (E3) x 1A (I_3) = 120 W.

20. Solve the circuit below:

I_t = 10A



Find the following values:

E_1 = ____V
E2 = ____V
E3 = ____V
E_t = ____V

I_t = 10 A
I_1 = ____A
I_2 = 2.5 A
I_3 = 2.5 A

R_t = ____Ω

P_t = ____ W
P1 = ____ W
P_2 = ____ W
P_3 = ____ W

Answer to Question 20:

E_1 = 200 V I_t = 10 A R_t = 20 Ω P_t = 2000 W

E_2 = 200 V I_1 = 5 A P_1 = 1000 W

E_3 = 200 V I_2 = 2.5 A P_2 = 500 W

E_t = 200 V I_3 = 2.5 A P_3 = 500 W

STUDY GUIDE 3ABR54530-II-2 and 3

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

ALTERNATING CURRENT WIRING SYSTEMS

April 1975

SHEPPARD AIR FORCE BASE

11-6

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Refr and Air-Cond Specialist
Dept of Civil Engineering Tng
Sheppard AFB, Texas

SG 3ABR54530-II-2
April 1975

ALTERNATING CURRENT WIRING SYSTEMS

OBJECTIVE

To help you in learning the:

- Definition of alternating current
- Characteristics and advantages of alternating current
- Principle of operation of transformers
- Purpose and principle of operation of various wiring systems
- Principle of operation of motors and motor starters

INTRODUCTION

When electricity first came into use, Mr. Edison held patent rights on the dynamos which were the power sources. These d.c. machines usually served an area of about a mile and a half radius because beyond this distance, line loss was too great. Since d.c. cannot be transformed, power was generated at the same voltage (about 110 volts) that was used in the homes and shops.

While d.c. was in use, and the existing patent rights were in force, experiments with a.c. were being performed. It was discovered that for commercial purposes, a.c. held many advantages.

1. Alternating current (a.c.) could be transformed - voltages could be stepped up or stepped down by use of a transformer.
2. Because a.c. could be transformed, smaller transmission lines could be used, and a.c. could be transmitted over longer distances more economically than d.c.
3. Most a.c. motors have no sliding contacts; therefore, they require little maintenance.

As patent rights expired, the use of a.c. spread until at the present, most of our commercial power is a.c.

FUNDAMENTALS OF A.C.

Definition of A.C.

Alternating current may be defined as a current which changes direction at regular intervals. (See figure 1.)

It may also be defined as a current which increases in value at a definite rate from zero to a maximum positive value, and again decreasing to zero, as shown in figure 2.

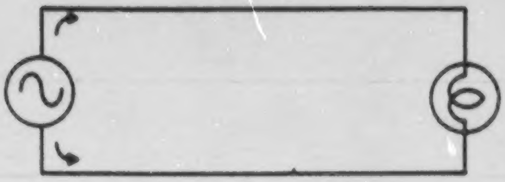


Figure 1. Alternating Current

Generation of A.C.

To generate a voltage mechanically, either a.c. or d.c., three things are needed; (1) a magnetic field, (2) conductors, and (3) relative motion. Combine these three, move the conductors or magnetic field, and a voltage will be generated.

A simple a.c. generator consists of a single turn coil or wire, a permanent magnet, two sliprings, and two brushes. Each end of the coil of wire is connected to a slipring. The two sliprings make up the rotor and this rotor is mounted between the poles of the magnet so that it is free to rotate on its axis. External connections to the sliprings are made by means of the brushes that are held stationary by the insulated brush holder and make continuous contact with the sliprings. (See figure 3.)

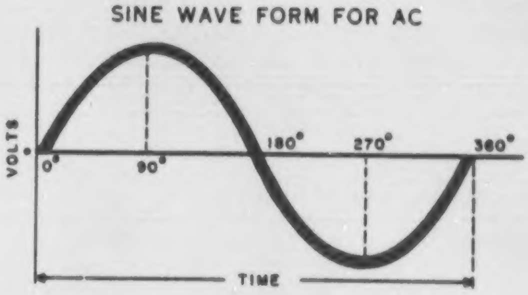


Figure 2. A.C. Voltage Curve

Generators are our primary source of a.c. All mechanical generators generate a.c.; however, d.c. generators convert a.c. to d.c. through the use of a commutator and brush assembly.

The Sine Wave

If you make a graph of the voltage induced in the conductor at various points, you will obtain an interesting curve, shown in figure 4. Plot the various points in degrees along the horizontal axis and the height of the voltage induced along the vertical axis. Use the horizontal axis as a reference for zero voltage. Consider the voltage induced in one direction as positive and that in the opposite direction as negative.

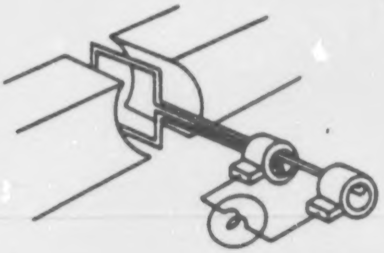


Figure 3. Simple Generator

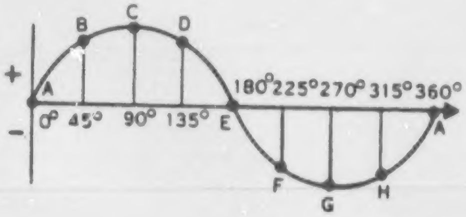


Figure 4. Graph of Induced Voltage

An Alternation

By studying the sine wave in figure 4, an alternation might be explained as a generation of voltage from zero to maximum and back to zero in only one direction. In figure 4, it would be represented between points A to E, or the 180 degrees represent the positive alternation. E to A in figure 4 represents the negative alternation.

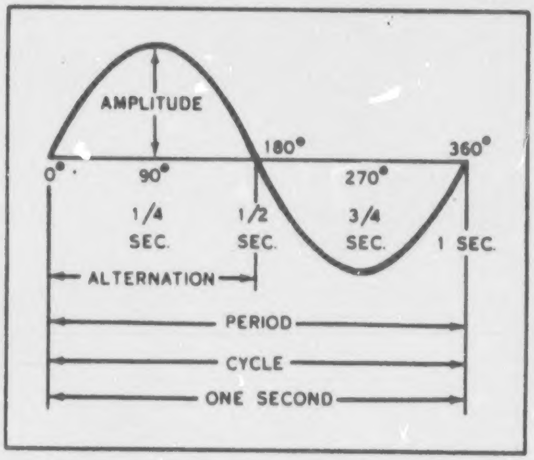


Figure 5. A.C. Cycle and Its Components

The Cycle

In electricity, the A.C. cycle is represented by the following symbol, ∿. Again study figure 4 for an explanation of the cycle. A to A (360 electrical degrees) represents one cycle of alternating current or voltage. A further explanation of the alternation and cycle can be seen in figure 5.

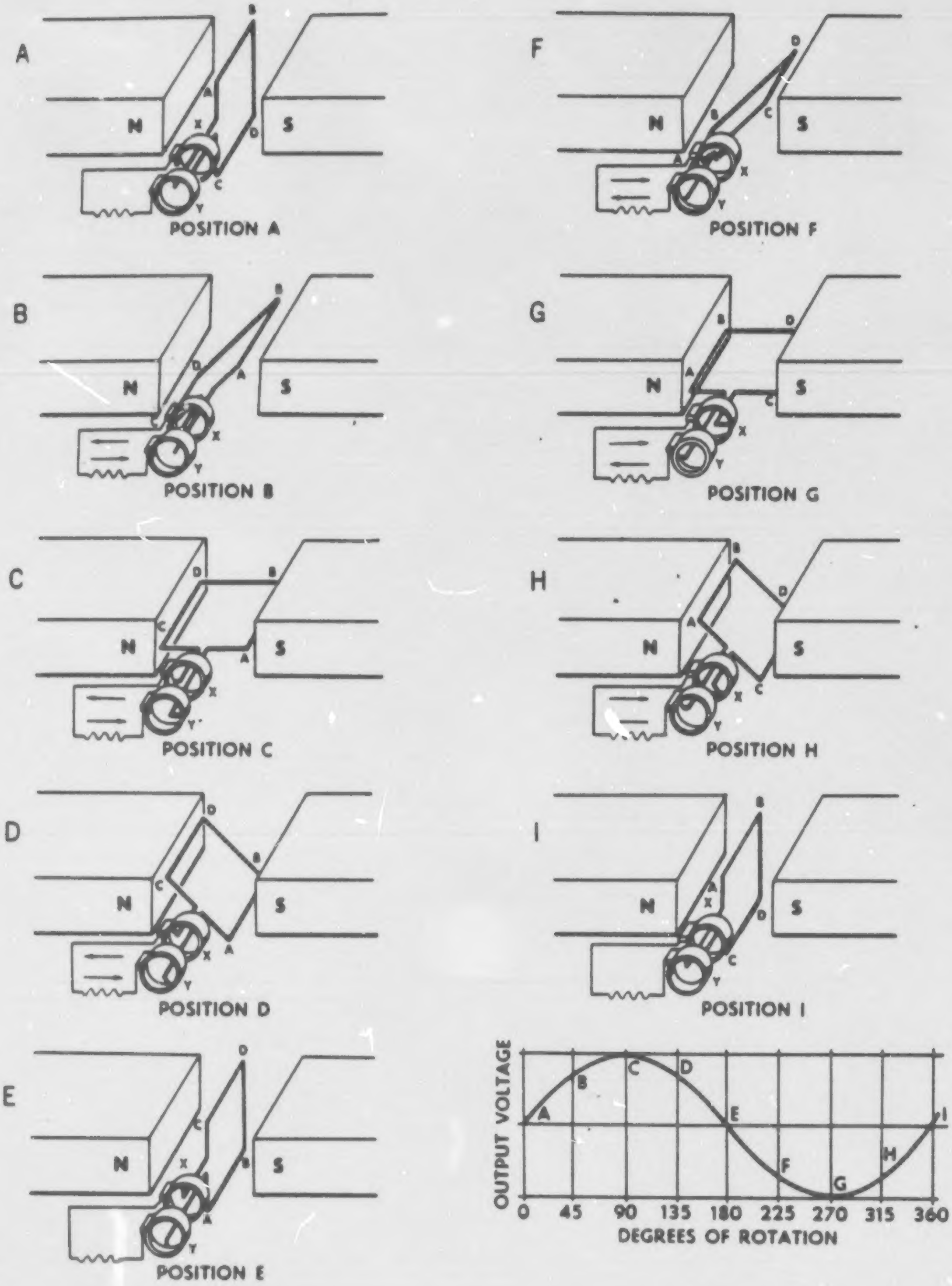

A
POSITION A
B
POSITION B
C
POSITION C
D
POSITION D
E
POSITION E
F
POSITION F
G
POSITION G
H
POSITION H
I
POSITION I
N
S
A
B
C
D
X
Y
OUTPUT VOLTAGE
DEGREES OF ROTATION
0
45
90
135
180
225
270
315
360

Figure 6. Generation of a Sine Wave

Frequency

The number of times each cycle occurs in a period of time is called the frequency. The frequency of an electric current or voltage specifies the number of times a cycle recurs in one second. The rate at which the current changes direction of flow is twice the frequency of the alternating current. If 120 reversals of current occur each second, the frequency of the alternating current is 120/2 or 60 cycles per second.

You have learned that current flows from negative to positive. For d. c. this is easily shown on a graph with a straight line. Alternating current also flows from negative to positive; however, polarity of conductors in an a. c. circuit is constantly changing. With sixty cycle current, the polarity of the conductors will change 120 times per second.

Most large a. c. generators are designed so that the magnetic field (an electromagnet) rotates, causing the lines of force to move across the stator coils, inducing a voltage in the stator coils.

Speed of commercial alternators is very closely controlled in order to keep the frequency cycles per second (cps) constant. Frequency of a. c. is standardized at 60 cps in the United States. Many foreign countries use 50 cycle current.

For a picture explanation of generation of a. c. sine waves, alternation, cycle and frequency, study figure 6.

Phase of Current and Voltage

When current and voltage pass through zero and reach maximum values at the same instant, current and voltage are said to be in phase. (See figure 7.)

Inductive Reactance

When an alternating current flows through a coil of wire, the rise and fall of the current flow, first in one direction, then in another, sets up an expanding and collapsing magnetic field about the coil, and

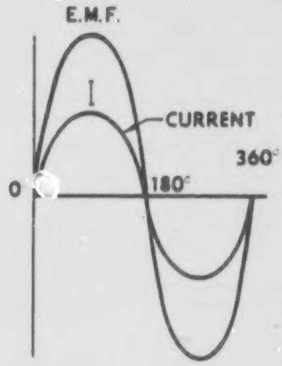


Figure 7. Current and Voltage in Phase

induces a voltage in it which is opposite in direction to the applied voltage and a current flow that opposes any change in the alternating current. This property of a coil to oppose any change in current flowing through it is called inductance.

The opposition to the flow of current which inductances put in a circuit is called inductive reactance. In a purely inductive circuit, the current reaches a maximum value later than the voltage, LAGGING the voltage by 90°, or 1/4 of a cycle. (Degree of lag may vary.) (See figure 8.)

Capacitive Reactance

Another important property in a.c. circuits, besides resistance and inductance, is capacitance. Capacitance is represented by a capacitor. (See figure 9.)

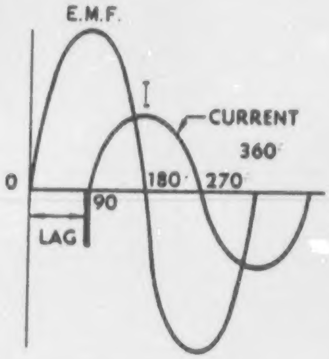


Figure 8. Effect of Inductance

Any two conductors separated by an insulator will have the property of capacitance. In any electrical circuit, a capacitor serves as a storehouse for electricity.

When an alternating current is impressed on the circuit, the charge on the plates constantly changes. In figure 10, the electricity must flow first from Y clockwise around to X, then from X counterclockwise around to Y.

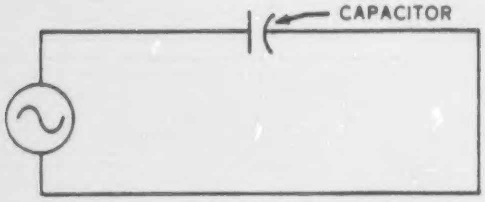


Figure 9. Capacitor in an A.C. Circuit

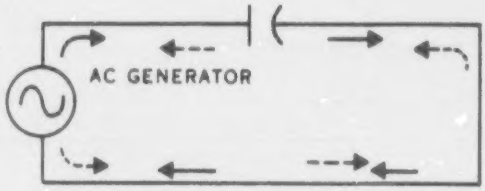


Figure 10. Capacitor in an A.C. Circuit

Although no current flows through the insulator between the plates of the capacitor, it is always flowing in the remainder of the circuit between X and Y. In a circuit in which there is only capacitance, current LEADS the applied voltage as contrasted with a circuit in which there is inductance, causing current to LAG the voltage. See the effect of capacitance in figure 11.

Capacitance offers resistance to any change in voltage. The opposition caused by a capacitor is called capacitive reactance.

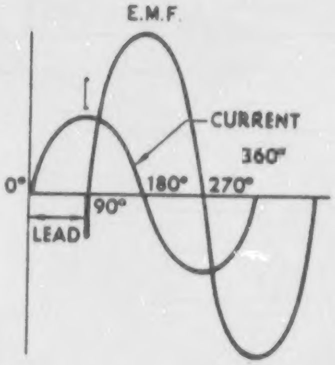


Figure 11. Effect of Capacitance

Rectifiers

We refer to the changing of a.c. current into direct current as rectification. Rectifiers are devices that act like a valve permitting current to flow in only one direction. Copper oxide and selenium rectifiers are the two principal types of metallic rectifiers. A selenium rectifier consists of a prepared film of selenium on a metallic substance such as iron. Both types permit current to flow more readily in one direction, from the metal to the film. Higher output voltage can be handled by connecting several in series. Higher current can be handled by arranging the rectifiers in parallel.

Using one rectifier the output will be half-wave pulsating d.c. (fig. 12). Two rectifiers (or four rectifiers as shown in figure 13), are required to obtain full-wave rectification.

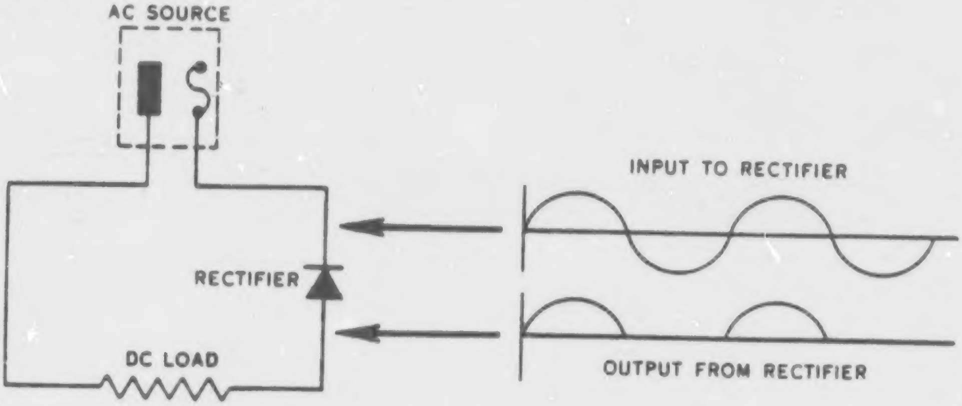


Figure 12. Half-Wave Rectification

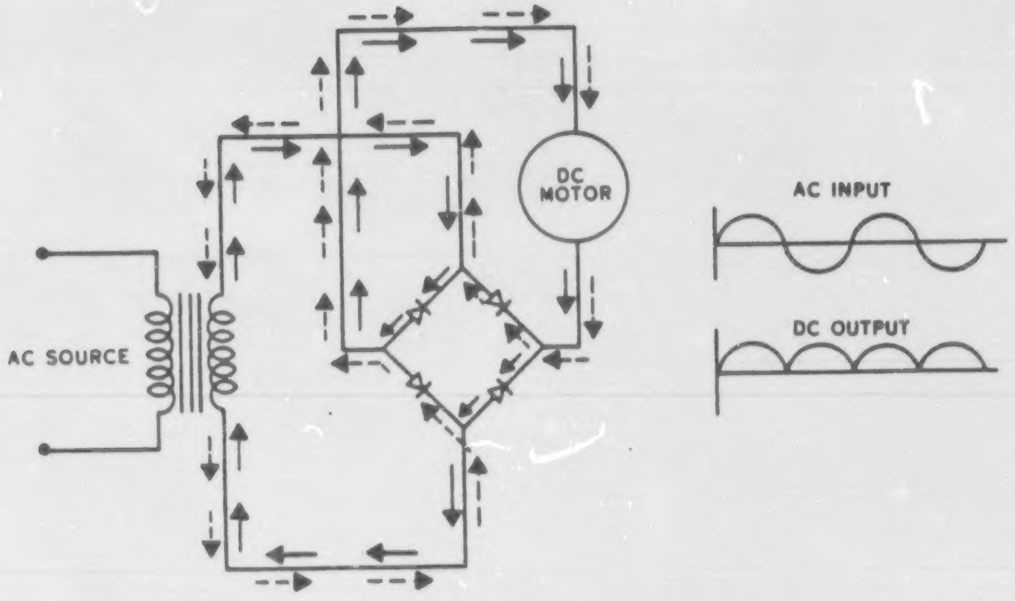


Figure 13. Full-Wave Rectification

TRANSFORMERS AND POWER

The term "transform" means to change. An electrical transformer is used to change the electrical characteristics of voltage and current. The use of transformers is widespread. Our everyday lives involve the use of many transformers, most of which are never seen by us.

Transformer Operation

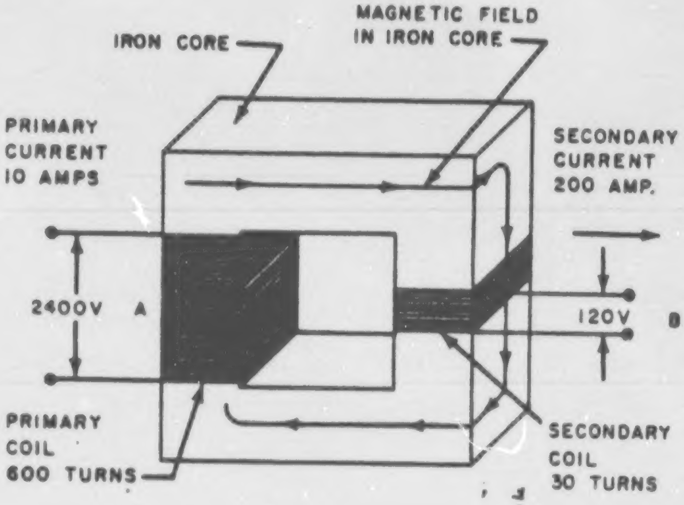
In studying characteristics of current, you have learned that about any conductor carrying current, there is a magnetic field, and that three things are required to generate voltage mechanically. They are:

1. A conductor.
2. A magnetic field.
3. Movement of the conductor across the magnetic field, or movement of the magnetic field across the conductor.

These characteristics and principles make operation of a transformer possible.

A transformer consists of three main parts (see figure 14). They are:

1. The primary coil - the coil to which voltage is applied.
2. The secondary coil - the coil from which the voltage is taken.
3. The core which may be iron or air serves to provide a path through which the magnetic lines of force travel.


IRON CORE
MAGNETIC FIELD IN IRON CORE
PRIMARY CURRENT 10 AMPS
SECONDARY CURRENT 200 AMP.
2400V
A
120V
B
PRIMARY COIL 600 TURNS
SECONDARY COIL 30 TURNS

$$\text{RATIO} = \frac{\text{TURNS IN PRIMARY}}{\text{TURNS IN SECONDARY}} = \frac{600}{30} = \frac{20}{1}$$

Figure 14. Transformer Construction

If an a. c. source of voltage is applied to the primary coil, a magnetic field will build up and collapse with each alternation. The lines of force from the magnetic field of the primary coil move across the secondary coil of the transformer, inducing a voltage in this coil. (A magnetic field is moving across a conductor.) The core provides a path for the magnetic field to travel through, and may consist of iron or air.

A direct ratio between the number of turns of wire in the primary coil and turns of wire in the secondary coil exists. If there are more turns of wire in the secondary coil than in the primary coil, voltage will be increased, or stepped up. If the secondary coil has fewer turns of wire than the primary coil, voltage will be decreased, or stepped down. To be more specific, if a transformer has a ratio of one turn on the primary to four turns on the secondary, secondary voltage will be four times greater than primary voltage.

The secondary coil of a transformer may have more than two electrical connections, or "taps," so that more than one voltage may be obtained from one transformer, as shown in figure 15. This transformer is referred to as a multitap transformer, and may be a combination step-up and step-down transformer.

The center tapped transformer is a multitap transformer, and is used to obtain two voltages, as shown in figure 16. Center tapped transformers are used to provide voltages of 110 and 220 volts in our homes and businesses.

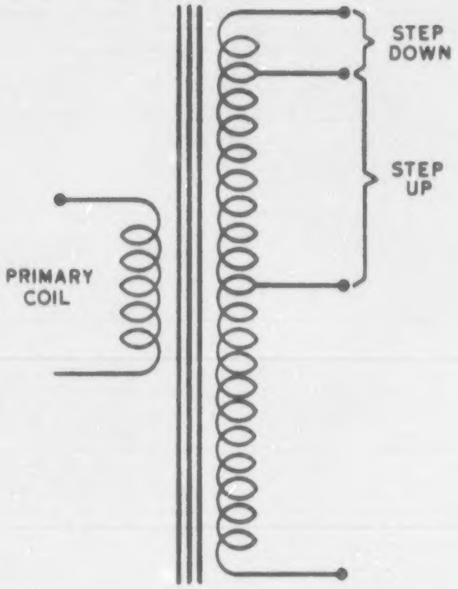


Figure 15. Multitap Transformer

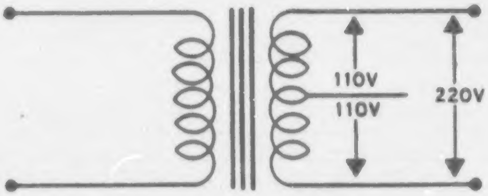


Figure 16. Center-Tap Transformer

Single-Phase Power

Frequently, we encounter the terms "single-phase" and "three-phase" when referring to electrical power. To the observer, single and three-phase transmission lines differ little. Since electricity is an abstract thing, the easiest way to explain phasing of electrical power systems is to explain the generation of power.

You have noted that, as a conductor moves through a magnetic field, a voltage is induced in that conductor. Figure 17 shows a single conductor moving through a magnetic field set up by a two pole magnet. As the conductor rotates, the maximum number of lines of force are cut as the conductor passes the pole pieces of the magnet, approaching one from the top; the other from the bottom, and alternating current is produced.

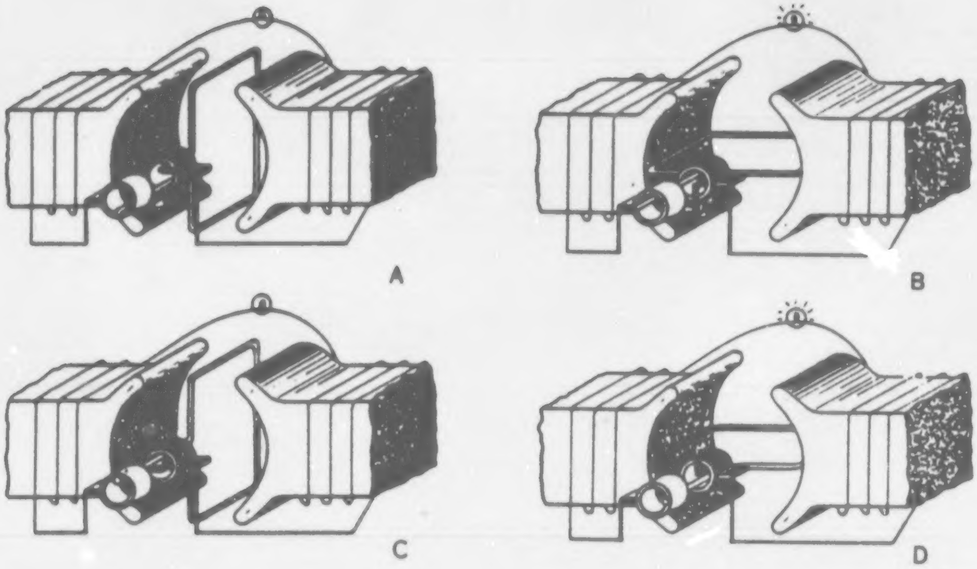


Figure 17.

The output voltage, if plotted on a graph, would be the sine wave form for a. c. (See figure 18.)

In this case, the conductor would have to make one complete turn to produce one complete cycle of a. c. This single conductor moving past the magnetic pole pieces produces a single waveform which we refer to as single-phase a. c. Note that two wires are required to transmit single-phase power.

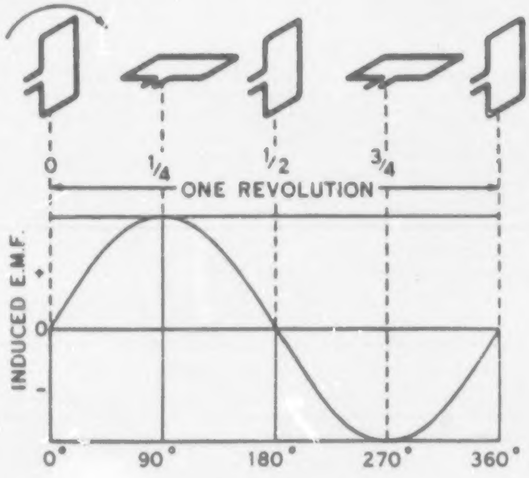


Figure 18.

Three-Phase Power

To generate three-phase power, three conductors, spaced 120 electrical degrees apart share the same magnetic field (see figure 19). Since the three conductors cannot cut the maximum number of lines of force at the same time, three waveforms, or phases are generated.

Figure 20 shows sine waves for three-phase a. c.

It would appear that six conductors would be required to transmit three-phase power, however, it has been learned that phases can be made to share conductors, and three conductors can efficiently conduct three-phase power (see figure 21).

The primary reasons for using three-phase power is for efficient transmission of power and operation of electrical motors. Three-phase motors are simple, rugged, and require little maintenance.

Three-Phase Transformer

Practically all power in the United States is generated as 60 cycle, three-phase alternating current and is supplied at the point of use as single-phase or three-phase alternating current. Voltages available at the point of use depend somewhat on the type of transformer connection.

The transformer we are concerned with is "WYE" connected. The wye connection is extensively used (figure 22) and is commonly referred to as a 3-phase, four-wire system.

The neutral wire allows single-phase 120 volt. From the neutral wire to any phase lead, 120 volt single-phase is available. Across any two-phase leads 208 volt single-phase is available. Across all three-phase leads 208 volt three-phase is available.

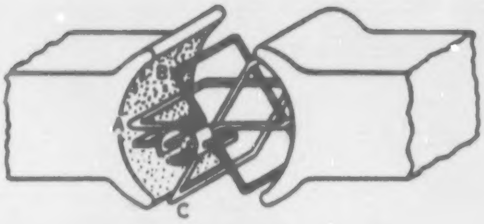


Figure 19.

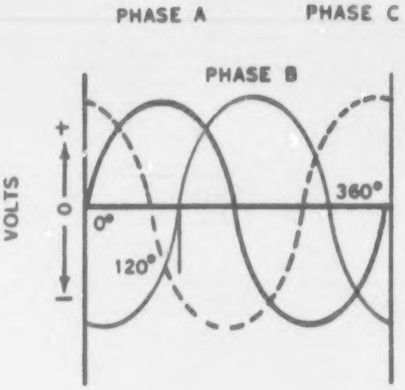


Figure 20. Output of a Three-phase Alternator

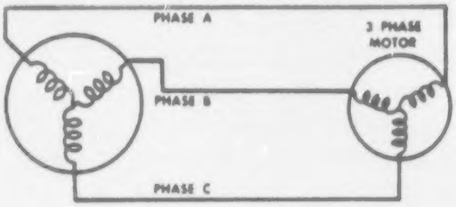


Figure 21. Three-phase Alternator with Three Conductors

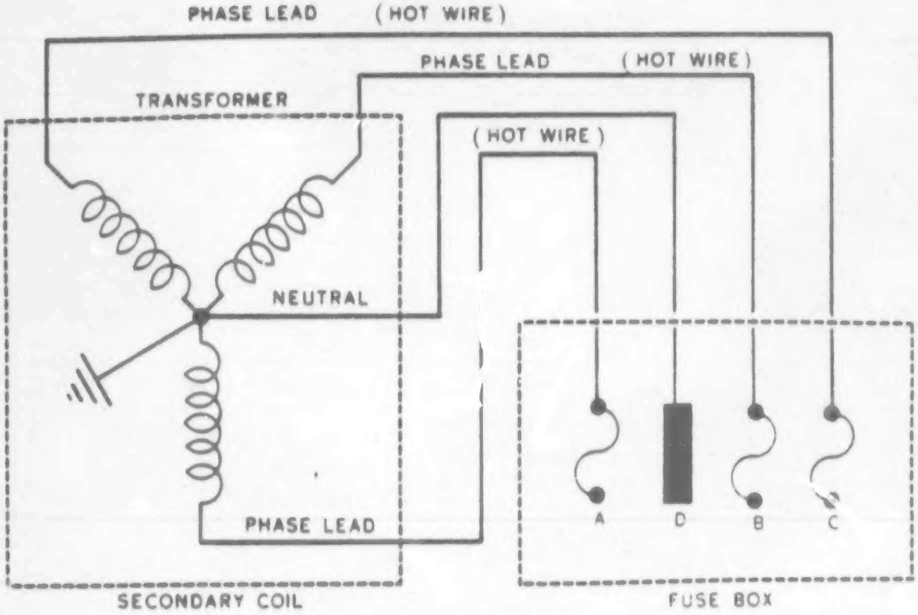

PHASE LEAD (HOT WIRE)
PHASE LEAD (HOT WIRE)
TRANSFORMER
(HOT WIRE)
NEUTRAL
PHASE LEAD
A
D
B
C
SECONDARY COIL
FUSE BOX

Figure 22. Four-wire System

Voltmeter readings with the wye connected secondary would be:

A-B = 208 volts
B-C = 208 volts
C-A = 208 volts

Neutral - A = 120 volts
Neutral - B = 120 volts
Neutral - C = 120 volts

Note that when the neutral wire is used with any combination of A, B, or C, 120 volts are available. Any combination of A-B, B-C, or A-C will provide 208 volts of single phase a. c. power. Three-phase power is obtained using A, B, and C.

Single-Phase Wiring Systems

When single-phase, 120-volt power is required, two wires will be sufficient for power transmission. One of these wires will be a white covered wire. This wire is referred to as the neutral wire, and should not be fused. The neutral wire should be grounded by means of a ground rod driven in the earth, or a cold water pipe may be used in some areas. Grounding one conductor provides a path for lightning (static electricity) to discharge to earth.

In addition to the neutral line being grounded, the "hot" line (ungrounded conductor) will be fused. In most wiring systems, a fuse or circuit breaker will be located in the main or feeder line. This master fuse or circuit breaker will be capable of carrying the entire load of all branch circuits, and can be used in emergencies to turn off all electrical power. (See figure 23.)

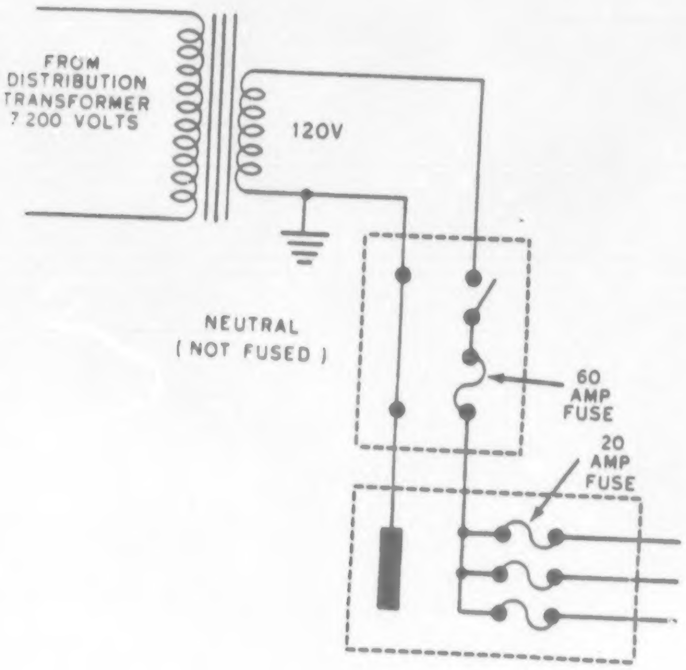


Figure 23. Fusing System

Branch circuits will be fused, or protected by circuit breakers with a capacity not to exceed the safe current rating of the wire in the circuit. All switches and control devices should be wired in the "hot" side of the circuit. This is a necessary safety precaution.

Most homes and buildings now have a requirement for both 120 and 208 volts. Normal lighting circuits and wall outlets are 120 volts. Appliances such as air conditioners, electric ranges, water heaters, dryers, and some power tools require 208 volts.

280

A multitap transformer is used to provide two voltages of single-phase power. The center tap of the transformer is the neutral, and is grounded to earth. The other two wires are "hot" wires, and will be fused. (See figure 24.)

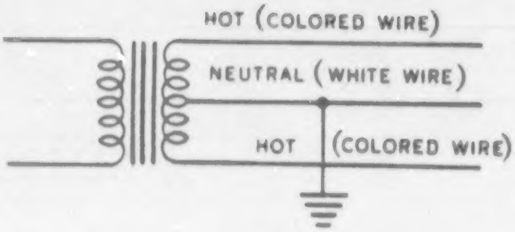


Figure 24. Multitap Transformer (Center-tap Transformer)

If the neutral (white) wire is in use as a conductor to a motor, it is called a neutral. Single and three-phase 208-volt motors do not require a neutral wire for their operation. If the white wire is a part of the motor circuit, a separate ground (green) wire will be used for the safety ground. The white wire should never serve a dual purpose--that of being a ground wire and a conductor to the motor.

For 120-volt circuits, the neutral (white) wire and a hot wire (colored) are used. Two hundred and eight-volt circuits use the two hot (colored) wires. Circuit breakers should be the dual type, meaning that if either hot wire is overloaded, both circuit breakers will trip simultaneously. Disconnecting both hot wires will prevent possible injury to anyone servicing the system. An equipment ground should be used on any electrical device, unless it is specially designed to prevent contact of any electrical conductor to exposed metal or the operator.

ACROSS-THE-LINE MOTOR STARTER

Motors of 3/4 horsepower and above require an across-the-line motor starter to provide motor protection, control starting and stopping, and to afford remote control.

Motor circuits and protective devices (fuses, circuit breakers, etc.) are sized so that their capacity is 125 percent of the normal full load amperage of a motor. Example: If a motor with a 20 ampere full load is protected with a 25 ampere fuse and a #10 electrical wire (see wire size chart), this motor could run indefinitely drawing 25 amperes. Since it is designed to run at 20 amperes under full load, running at 25 amperes would eventually burn it out or the windings would be permanently damaged. To prevent this damage and avoid costly replacement of the larger motors, the across-the-line motor starters are used on 3/4 horsepower and above motors.

A motor starter consists of three or four sets of heavy contacts used for closing the circuit to the motor, thermal switches, heaters, and an electromagnet (coil). The contacts are operated by an electromagnet, or solenoid referred to as a holding coil. The contacts are closed when voltage is applied to the holding coil. Usually the voltage of the holding coil is the same as that of the motor controlled by the starter; however, applications where a 24-volt coil is used to control a 208-volt motor are not uncommon.

Two circuits are used in motor starters. The circuit used to energize the holding coil is referred to as the "control circuit." It contains a manually operated switch or an automatic switch (thermostat), thermal switch, and the holding coil. The circuit to the motor is referred to as the "load circuit" and contains the load contacts (movable contacts), heater or heaters and the load (motor).

The heaters are special resistors installed in the load circuit. The heat given off by these heaters is proportional to the current flow. As current flow increases, heat from the heater increases. Located adjacent to the heaters are "normally" closed thermal (heat operated) switches. The thermal switches are in the control circuit. If current to the motor increases beyond safe limits, heat from the heater causes the thermal switch to open and the holding coil is deenergized, opening the load circuit.

The contacts of the thermal switches are usually held open by a mechanical catch or spring and must be closed (reset) manually.

In addition to the thermal switch or switches used in the control circuit, an additional switch or switches may be used to control the motor starter. For example, a manually operated single-pole, single-throw switch located in the control circuit can be used to energize, or deenergize the holding coil of a motor starter if manual control is desired. In the refrigeration field, single-pole, single-throw switches controlled by pressure (pressure controls) or temperature (thermostats) are used extensively in the control circuits of motor starters to start and stop motors (see figure 25).

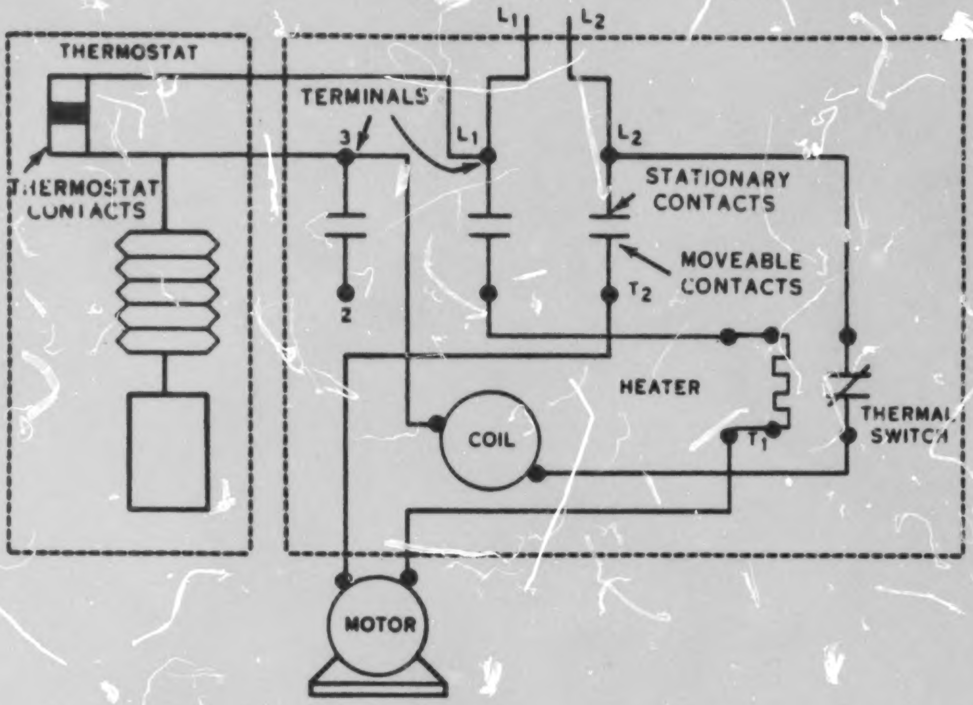

L1
L2
THERMOSTAT
TERMINALS
3
L1
L2
THERMOSTAT CONTACTS
STATIONARY CONTACTS
MOVEABLE CONTACTS
2
T2
HEATER
COIL
T1
THERMAL SWITCH
MOTOR

Figure 25. Single-phase Across the Line Motor Starter

Sizing of the motor starter heaters is very important. Heaters that have greater current ratings than the motor being operated will not properly protect the motor. Heaters that are too small will cause nuisance tripping due to normal current flow.

To determine the proper heater for a given motor starter application, you must first determine the full load amperage of the motor by checking the data plate information. Then, using the conversion table for the specific motor starter, find the heater number that is designed for the full load amperage of the motor. Usually, this information is included in the cover of the motor starter. Heaters from one name brand motor starter are not interchangeable with other manufacturer's products. No attempt should be made to interchange heaters.

Single-phase motor starters require one heater and one thermal switch. (See figure 25.) Three-phase motor starters require a minimum of two heaters and two thermal switches. (See figure 26.)

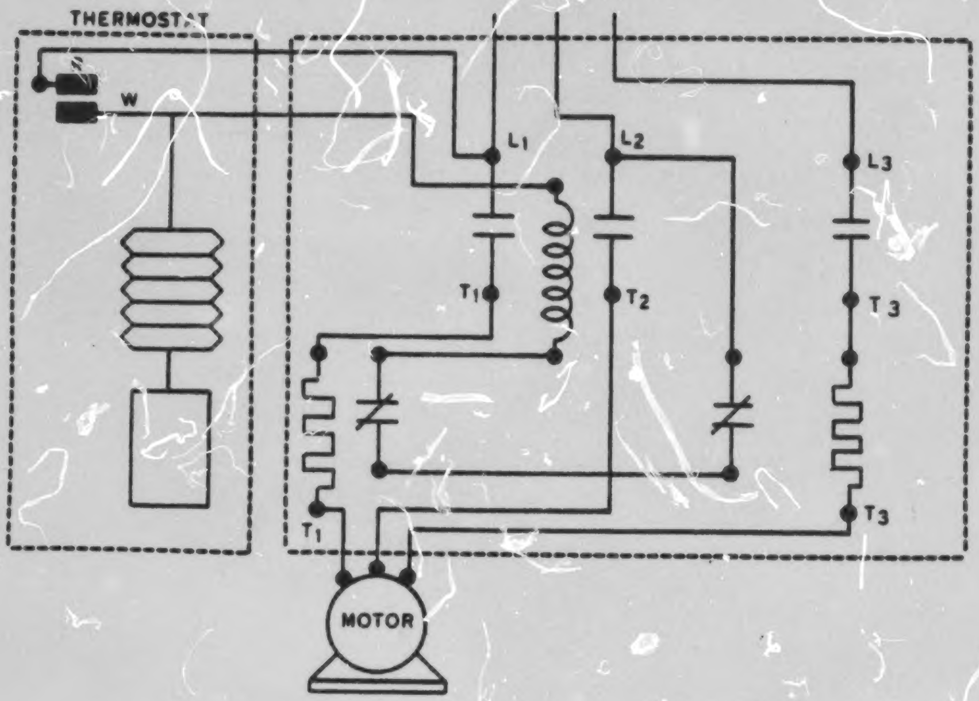


Figure 26. Three-phase Across the Line Motor Starter

Many holding coils are designed for dual voltage applications, for example one coil may operate on 120 volts and by changing one connection the same coil can be used on 208 volts. Actually, these coils are center tapped and when 120 volt operation is desired, only half the coil is being energized.

The motor starters shown in figure 25 and 26 apply full line voltage to the motor when the load contacts close. It is important that you understand their operation.

Maintenance and Troubleshooting Motor Starters

Maintenance and troubleshooting motor starters is pretty much limited to three areas--load contacts, the holding coil, and the heaters.

In the event a motor starter will not energize, a voltmeter check at the holding coil will determine if all control circuit switches are closed.

If no voltage is applied to the coil, push the reset button, and check the controlling switch, or switches (thermostat, pressure switch, or manual switch) to see that their contacts are closed. If voltage is applied to the holding coil, but the contacts still will not close, either the contacts are held open mechanically, or the holding coil is open. Check for an open coil by turning off the power, and checking for continuity across the terminals being used for the holding coil. A reading of infinity with an ohmmeter indicates an open coil. Most holding coils are easily replaced. Replace the faulty coil with a like part.

Continuity of the heaters of a motor starter can be easily checked by turning off the power, and checking across the heater terminals with an ohmmeter. Heaters should show continuity. Heaters for small motors will show very low resistance; resistance of heaters for large motors may not be measurable. If a heater fails to show continuity, replacement is required.

The load contacts of motor starters are most susceptible to trouble, because of heavy current, and the frequent opening and closing required.

A voltmeter is the best troubleshooting tool a specialist has when it comes to checking load contacts. Connect the voltmeter leads in parallel to each set of contacts, and energize the holding coil. A voltmeter reading with the contacts closed means that there is resistance across the contacts, and replacement or cleaning is in order. Repeat this procedure for each set of contacts.

ALTERNATING CURRENT MOTORS

An electric motor is a device used to change electrical energy to mechanical energy. There are numerous types of electric motors in use throughout the Air Force today and a basic understanding of their operation is essential.

All electric motors are constructed of the same major components:

STATOR. The stationary portion of the motor which contains the start and run windings.

ROTOR. The movable portion, constructed of iron or copper bars joined by end rings and covered with an iron core.

END BELLS. Located at the ends of the stator, complete the frame and house the bearings that allow the rotor to turn smoothly.

The most common types of motors used today derive their name from the type of rotor used, operating principle, and their starting mechanism. The major type of motor that you will be working with is called the squirrel-cage induction motor. The term squirrel cage is used because the rotor looks like the exercise wheel used inside a squirrel cage. The term induction refers to the principle of operation which will be studied in this section.

To operate an induction motor, two requirements must be met; a rotating magnetic field must be set up in the stator and a magnetic field must be present in the rotor.

Three-Phase Motors

To explain how the magnetic fields are created, a study of the basic three-phase motor will enable you to view the step-by-step process of starting a magnetic field to rotate.

The stator of a three-phase motor is wound with three sets of poles (windings) placed 120 electrical degrees apart (figure 27).

Phase 1 is 120 electrical degrees from phase 2. Phase 2 is 120 electrical degrees from phase 3, which is 120 electrical degrees from phase 1. When the three-phase alternating current is applied to the windings, what appears to be rotating magnetic field will be created. To explain how this field is created, a study of the three-phase a.c. sine wave as current flows through the motor and its effect is necessary.

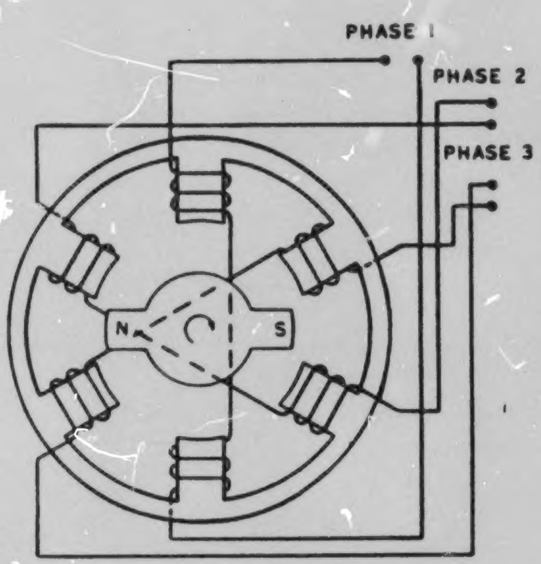


Figure 27. Three-phase Windings 120 Degrees Apart

Figure 28 shows the stator and entering current of three-phase power. Note that phase 1 is at maximum and phases 2 and 3 are below maximum but equal. This condition will cause phase 1 and its poles to set up a strong magnetic field, while phases 2 and 3 set up weaker magnetic fields.

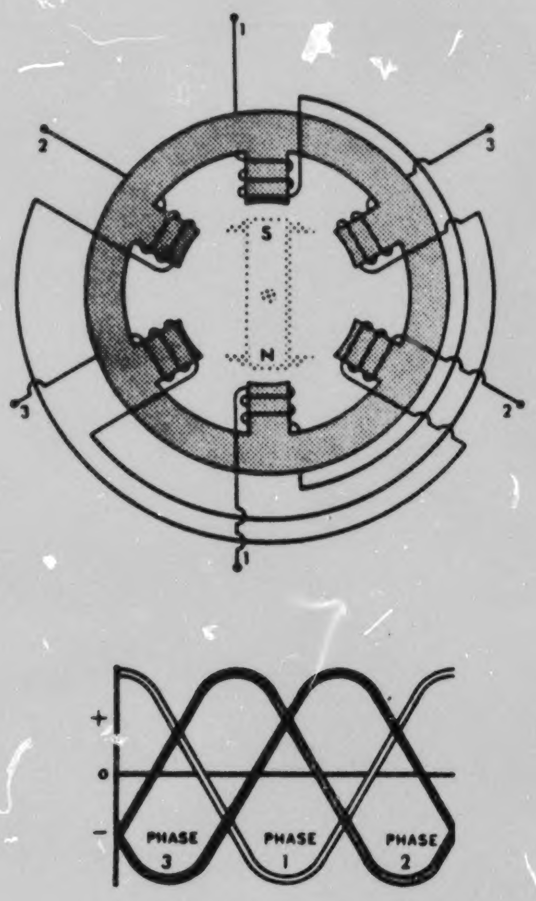


Figure 28. Current flow in phase 1 sets up strong field.

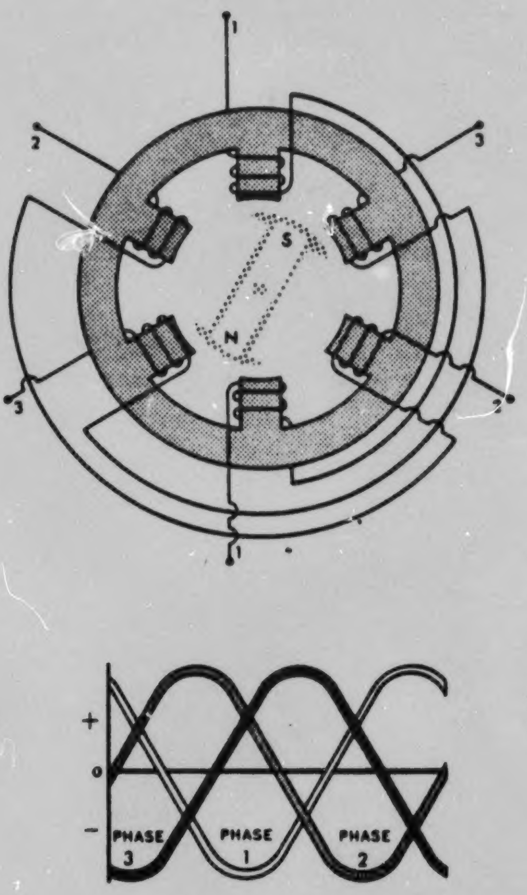


Figure 29. Current flow in phases 1 and 3. One and 3 now have strong field.

Figure 29 shows the sine wave and current 22.5 electrical degrees later. Now phase 1 and phase 3 are equal, but opposite and phase 2 is at zero. Phase 2 does not have a magnetic field. The magnetic field is now shifted from its original position and is now between poles 1 and 3.

Figure 30 shows the relationship after the current shifts another 22.5 electrical degrees. The magnetic field is now strongest in phase 3 and phase 1 and 2 are equal but below maximum.

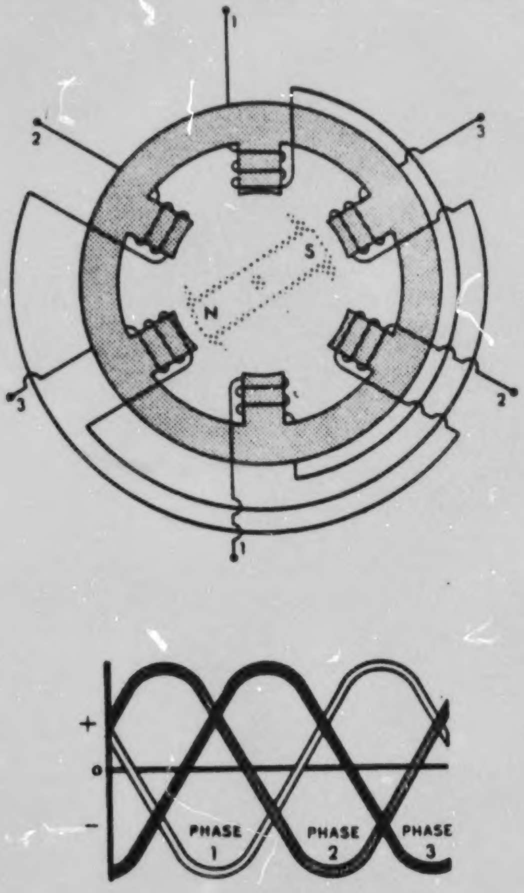


Figure 30. Current applied to phase 3 creates a strong magnetic field there.

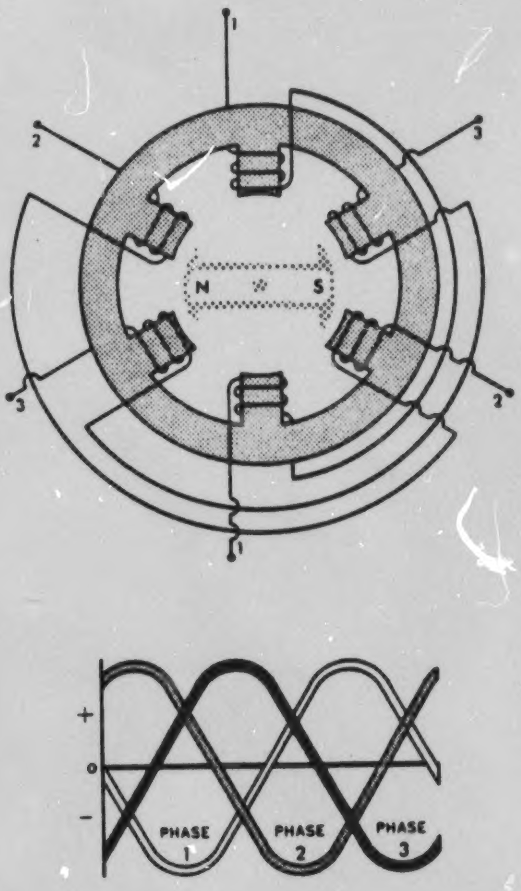


Figure 31. Phases 2 and 3 now each have current flow and a magnetic field.

Figure 31 shows another shift along the sine wave and finds that poles of phases 2 and 3 have set up and share a common magnetic field, while phase 1 is at 0 with no magnetic field.

As the current continues to alternate, the magnetic field will alternate with it. Each change that occurs in the current will create a change in the magnetic field. When this current is applied to motor windings, it sets up an alternating magnetic field which follows the changes in applied current.

The alternating magnetic field in the stator will cut across the copper bars in the rotor, inducing current in them. As the rotor current is induced, a magnetic field will develop around the rods. The magnetic field in the rotor reacts with the magnetic field in the stator producing a torque, causing the rotor to turn.

The superb starting torque of a three-phase motor makes it ideal for application on equipment that requires high torque such as large fans, compressors, and large pumps.

To reverse direction of rotation of a three-phase motor, just reverse any two power leads.

Maintenance of three-phase motors is pretty much limited to lubricating and cleaning. If sealed bearings are used, only cleaning is required. Wiping excessive oil from the motor and an occasional blowing out of lint and dirt will increase motor life by allowing the motor to operate cooler.

The greatest enemy to a three-phase motor is single-phasing. This is a condition that exists when one line of a three-phase system is open, causing the motor to operate on single-phase power. Single phasing is evidenced by loss of speed if the motor is running. Failure to start or reversal of direction of rotation may occur if a three-phase motor attempts to start on single-phase power. Single phasing causes motors to overheat rapidly and if the condition persists, the motor will burn out.

Three-phase motors can be checked electrically by taking three sets of ohmmeter readings across the motor leads (l_1 to l_2, l_2 to l_3, and l_1 to l_3). All three sets of windings should have the same resistance. Infinity readings indicate open motor windings. Low resistance readings are quite common for large motors; however, a zero ohmmeter reading may indicate a shorted motor winding. If there is reason to suspect a shorted winding, an operational check can be made with a clamp-on ammeter. Current flow in all three phases should be equal. Variations in current flow may be due to shorted motor windings.

Grounded motor windings of three-phase motors can be checked by placing one lead of an ohmmeter on the motor lead, and the other on the frame of the motor. Any reading of continuity means that insulation has failed, and the motor should be repaired or replaced before further attempting to use it.

Single-Phase Motors

After attaining running speed, the single-phase motor operates on the same principle as that of a three-phase motor. However, a single-phase motor needs a supplementary device to make the initial start-up.

If a single-phase motor had only a single set of windings in the stator (figure 32) and was connected to single-phase power, it would hum, but would not rotate. However, if while it was humming, the shaft was rotated by hand (in either direction) the motor would gain speed and continue to operate satisfactorily. The turning of the shaft starts the rotation of the magnetic field and establishes the induction in the rotor.

All that is necessary to make a single-phase motor self-starting is to equip it with a device which will start the rotation. The "induction-start, induction-run" (split-phase) and the "capacitor" start type motors are made self-starting by adding a second winding to the stator (figure 33).

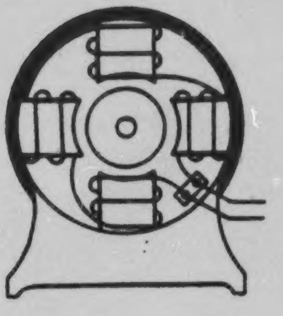


Figure 32. 1ϕ Motor with Single Set of Windings

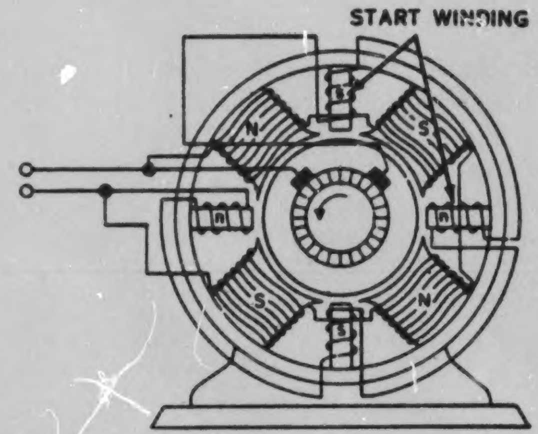


Figure 33. 1ϕ Motor with 2 Windings

Induction-Start, Induction-Run (Split-phase) Motor

In the induction-start, induction-run (split-phase) motor, the second or "start" windings contain a much greater number of turns (coils) than are in the "run" windings. Because of the higher inductance in the start windings, the current in it lags behind the current in the run windings. When the start current lags behind the run current, the two currents are "out-of-phase" as in the case of the three-phase motor. This condition produces the rotating magnetic field needed to start the motor. When the motor reaches 3/4 or 75 percent of the running speed, a centrifugal switch automatically opens the electrical circuit in the start windings. From this point on, the motor continues to operate by induction.

The use of the induction-start, induction-run (split-phase motor is confined to applications with light loads. This is because the starting torque (initial turning ability) is not very strong. Small fans, pumps, blowers, and refrigeration systems with capillary tubes that equalize pressure when off, use this motor.

Capacitor-Start Motor

The "Capacitor-start" motor has a start winding in addition to the run winding. In this type motor, there is a capacitor connected in series with the start winding. The capacitor produces a "leading current" which results in the start winding current and magnetic field being "out-of-phase" with the run winding current and magnetic field. This condition produces the rotating magnetic field needed to start the motor. When the motor reaches 3/4 or 75 percent of the running speed, a centrifugal switch automatically opens the electrical circuit in the start windings. From this point on, the motor continues to operate by induction.

Because the capacitor has a greater phase-splitting capability, this type motor has a greater starting torque than the induction start motor and can be used on heavier loads. It is able to start compressors with high loads and is used to run medium sized blowers, pumps, and fans.

To reverse the direction of rotation of either the "split-phase" or the "capacitor" start motors, reverse either the start or run winding leads.

If a capacitor-start motor fails to operate, it may be the capacitor which is at fault. To check a capacitor to determine its condition, you must first discharge it. This discharging is accomplished by crossing (shorting) the two terminal leads together. CAUTION: Do not touch the bare portion of the capacitor leads. It is advisable to always discharge a capacitor with a resistor in series with the terminals. This prevents any large surge of current that could damage the capacitor and injure you. After discharging the capacitor, remove it from the unit. Obtain an ohmmeter and set it on Rx 100 scale. Place the test leads on the capacitor terminals. If the capacitor is good, the needle will move to an ohm reading and then move slowly back to infinity. If the meter reads zero ohms, the capacitor is grounded or shorted and if the meter reads infinity, the capacitor has an open and must be replaced (figure 34).

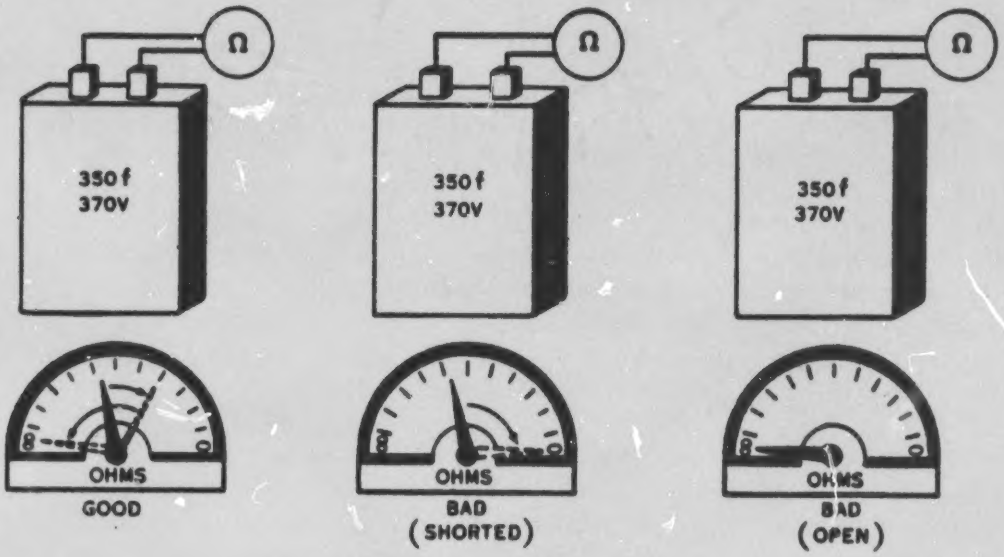

Ω
350 f
370V
OHMS
GOOD
Ω
350 f
370V
OHMS
BAD
(SHORTED)
Ω
350 f
370V
OHMS
BAD
(OPEN)

Figure 34. Capacitor Check

Shaded-Pole Motor

The simplest single-phase motor is the shaded pole motor. A "shaded-pole" motor is one that has only a single winding in its stator. The shift of the magnetic field and its accompanying rotation is obtained by "shading" a portion of the pole.

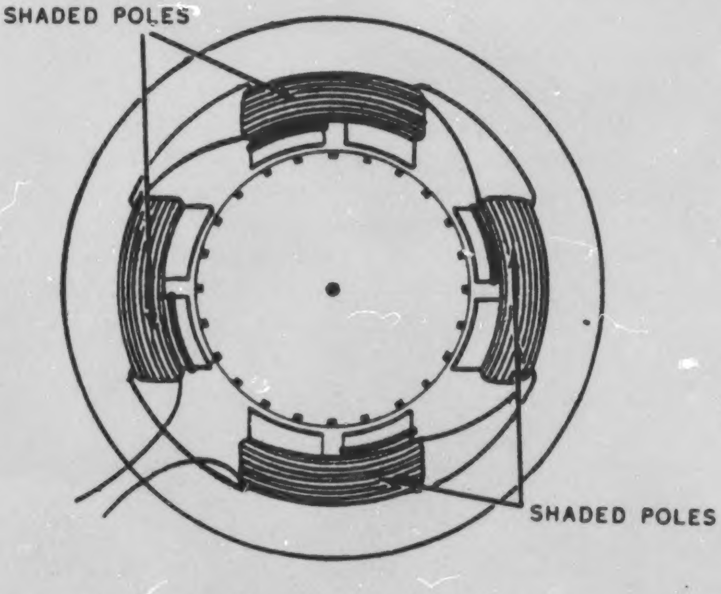

SHADED POLES
SHADED POLES

Figure 35. Shaded Pole Motor

The shading coil is a copper loop similar to a metal ring. The shading coil is recessed off-center on the pole. Magnetism induced in this loop is "out-of-phase" with the magnetism accompanying the main windings. Being out-of-phase shifts or sets the magnetic field in rotation. The squirrel-cage rotor is then dragged around by induction.

The shaded-pole motor has very little starting torque and can be used only on applications with very light loads such as clocks, small fans, and pumps.

The shaded-pole motor comes with the direction of rotation stamped on the housing, this direction can only be changed by disassembly of the motor and is not practical.

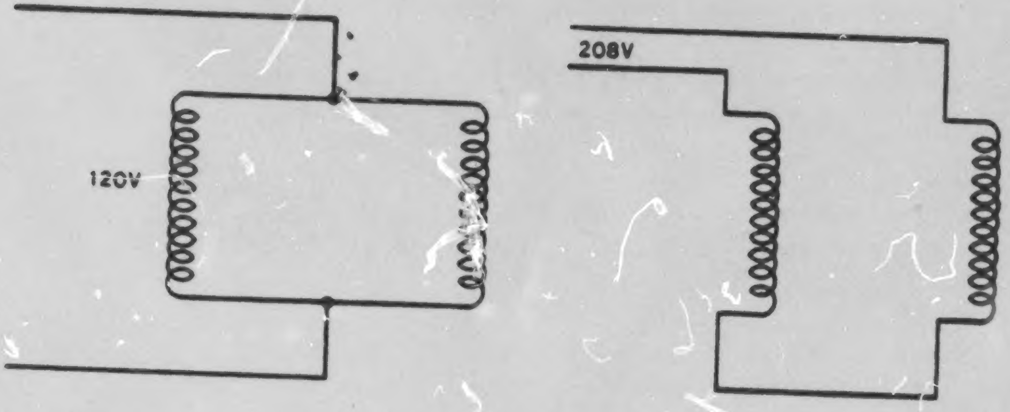
SYNCHRONOUS MOTOR. The synchronous motor is so named because the rotor is synchronized with the rotating magnetic field in the stator windings. The rotor is constructed as a combination squirrel cage and wound type, or in the case of the electric clock a small steel disk is used. The magnetic field between the poles magnetizes the disk. The poles of the rotor will lock in with the poles of the stator and the rotor will rotate in step with the stator's alternations.

The speed of rotation of the synchronous motor is determined by the number of poles and the frequency of the alternating current applied to the stator. They come in speeds ranging from four poles (1800 RPM), to 100 poles (72 RPM).

The chief advantage of the synchronous motor is its constant speed under varying loads. This makes it suitable for operating blowers, air compressors, centrifugal pumps, and the household clock.

Dual Voltage Motors

Some motors are designed to operate on dual voltages, for example, 120 or 208 volts. This is accomplished by bringing the leads of the coils out of the winding separately, so that the coils may be wired in parallel for low voltage, and in series for high voltage (the voltage drop across each individual coil is the same for both high and low voltage operation). (See figure 36.)



Parallel Operation for Low Voltage
Series Operation for High Voltage

Two Pole Motor Wires for 208 Volt Operation

Figure 36.

High voltage operation of dual voltage motors is desirable because greater economy of operation may be realized in some applications. Motor data plates usually show high and low voltage connections.

Speed of Induction Motors

The speed of induction motors depends on two things-- the number of poles in the motor, and the frequency of the alternating current. The synchronous speed (speed if there is no magnetic slip) of a motor can be determined, using the formular, $RPM = \frac{2}{NP} \times 60 \times f$, where NP= number of poles of a motor, and f = cycles per second. Sixty is a constant number, because there are sixty seconds per minute, and the speed of the motor is measured in RPM; while frequency is measured in cycles per seconds.

Example: How fast will a two-pole motor run on 60-cycle current?

$$RPM = \frac{2}{NP} \times 60 \times f$$

$$RPM = \frac{2}{2} \times 60 \times 60 = \frac{7200}{2} = 3600 \text{ RPM}$$

The synchronous speed of the motor is 3600 rpm, actual speed would be about 3450 rpm.

Magnetic slip is necessary in order for the motor to develop torque.

Some induction motors are designed to operate on dual frequencies--50 and 60 cycle current. Operation on 50 cycle current results in a decrease in RPM.

Installation and Maintenance of Motors

Motors chosen for a specific task must be properly rated and protected for their work. Such factors as size, type of voltage, inclosure, speed, mounting requirements, direction of rotation, torque, type of bearings, and temperature must be considered. The foundation of the motor should be securely mounted and as free as possible from vibration. They must be aligned properly to prevent excess wear and vibration.

When V-belts connect a motor to the load, the belt tension should be from 1/2 to 3/4 of an inch deflection with one to two pounds of pressure applied midway of the motor and load pulleys.

Motors with sleeve or bushing type bearings are for light duty horizontal mounting. Roller or ball type bearings are used in high torque motors and are suitable for horizontal or vertical mounting.

No specific instructions can be given for lubrication that will apply to all motors. It is necessary for you to consult the attached lubrication plate and/or pertinent lubrication order or technical manual pertaining to the material of which the motor is a part. All lubrication fittings should be kept clean to prevent dirt from getting into the bearings. While it is important that motor bearings have enough lubricant, too much lubricant will also damage the motor. Excess oil and grease will get into and damage the windings and also spill onto the floor, creating a safety hazard.

SUMMARY

Alternating current is produced by a mechanical generator. Periodic changes in polarity of the conductors causes current to flow in one direction, stop, then flow in the opposite direction.

A.C. can be transformed, transmitted over long distances, produced economically, and is ideal for operating motors.

Standard frequency of current in the United States is 60 cycles per second. Single-phase power is used for lighting, small motors, and appliances. Three phase power is ideal for operation of large motors.

A coil in an a.c. circuit causes inductive reactance, a condition where current lags voltage.

A capacitor in an a.c. circuit causes capacitive reactance. Capacitive reactance causes current to lead voltage.

An electric motor is a device used to change electrical energy into mechanical energy. Shaded-pole, split-phase, capacitor-start, and synchronous motors are single-phase motors used in the refrigeration field. Three-phase motors are used for large refrigeration and air-conditioning systems.

Wiring systems using two wires make only one voltage available. Three wire systems are used to provide dual voltage, single-phase power when attached to a center-tapped transformer. Three-wire systems are also used to transmit three-phase power. Four-wire systems make voltages of 120 and 208 volts, single-phase power, and 208 volts three-phase power available. Fuses or circuit breakers are used to protect the main power lines, as well as the branch circuits. Wire sizes should be determined by the load placed on the circuit.

QUESTIONS

1. What is the source of a.c.?

2. Why does the current periodically change direction of flow in an a.c. circuit?

3. List three advantages of a.c.

4. What are the three parts of a transformer?

5. What type transformer is used to provide dual voltages?

6. What is meant by the term "in phase?"

7. How does a coil in an a.c. circuit affect the relationship of current and voltage?

8. How does a capacitor affect the relationship of current and voltage?

9. What effect of current flow makes the operation of motors possible?

10. Which of the single-phase motors has the poorest starting torque?

11. Which of the single-phase motors has the best starting torque?

12. How is a three-phase motor reversed?

13. List three safety practices to observe when working on an a.c. system.

14. Why are a.c. power lines grounded to earth?

REFERENCES

1. TO 31-3-1, Electrical Fundamentals.
2. Textbook, Modern Refrigeration and Air Conditioning--Althouse and Turnquist.
3. Textbook, Commercial and Industrial Refrigeration--Nelson.
4. Electrical Manuals--Coyne.
5. Electrical Manuals--Audel.

SG 3ABR54530-II-3
April 1975

ELECTRICAL TROUBLESHOOTING

OBJECTIVE

To help you in learning to trace single and three-phase electrical diagrams, types of electrical troubles, and troubleshooting procedures.

INTRODUCTION

If you will review Study Guide 3ABR54530-II-2, you will find that troubleshooting is defined as a means of systematically locating faults in an electrical system. There are usually three kinds of troubles: opens, shorts,and low power. You will find that troubleshooting a.c. circuits is very similar to troubleshooting d.c. circuits. In both cases, the same procedure and same testing devices are used. You may, however, find that a.c. circuits are slightly more complicated than d.c. since some a.c. circuits are in three-wire and four-wire systems.

A.C. CIRCUITS

Wiring Diagrams

Before operating a circuit, you should first know the circuit. A layout of the circuit can be found in wiring diagrams of the system. For example, look at the diagram in figure 37. By studying motor "G" circuit, you will find that the contacts in relay "H" must be in a closed position before motor "G" will operate also, in order to close the contacts in relay "H," switch "D" must be closed to energize the coil of relay "H." You can determine from this that for motor "G" to operate, two circuits must be in operating condition. Such a study must be made of any circuit before attempting to operate it or troubleshoot it.

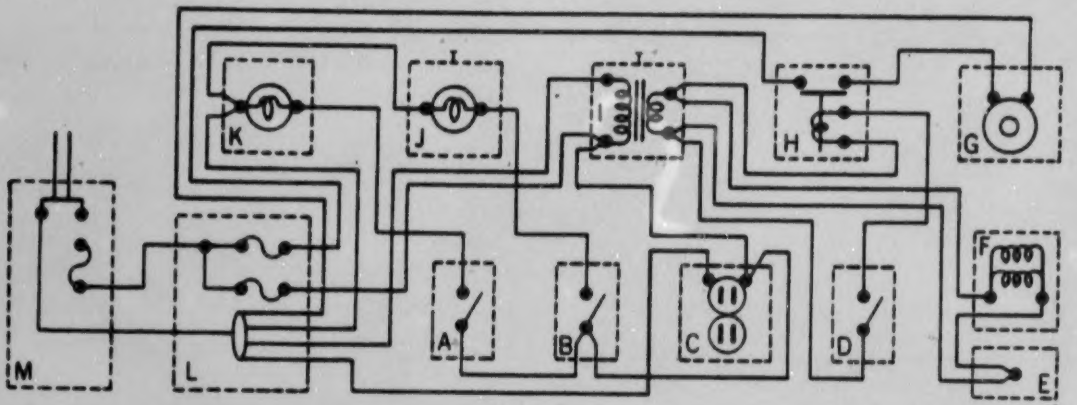


Figure 37. Single-phase System Diagram

Operational Check

Studying the diagram will give you knowledge of how the circuit should normally operate. An operational check should then be made to determine if the circuit is faulty. For example, again refer to motor "G" circuit in figure 37. An operational check would be performed by closing switch "D." Relay "H" should close and the motor shaft start turning. If anything other than this should take place, the circuit is defective and an analysis as to the type of trouble and its location must be made.

Types of Troubles

In practically all cases, the actual trouble will be one of the following types: an open, a short, or low power. Each one will be reviewed.

OPENS. An open circuit is one that has a break in any part of the electrical circuit between the unit of resistance and the source of voltage. The effect of an open is that no current can flow so the unit is inoperative. (In some instances, a unit might be "fed back" through another circuit.) See the effect of an open in figures 38 and 39.

In the case of figure 38, only L_2 would be inoperative. In figure 39 you will see that the location of the open causes L_2 and L_3 both to become inoperative.

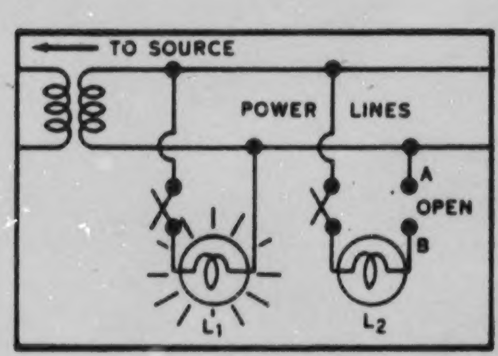


Figure 38. Open Circuit Single-phase Two-Wire System, "L_2" Out

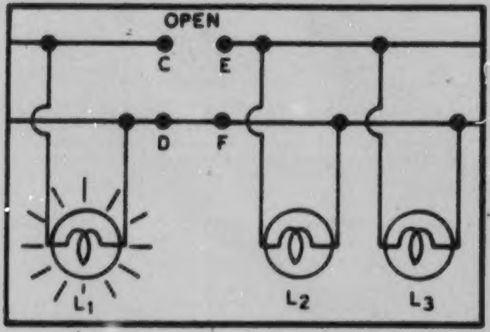


Figure 39. Open Circuit Single-Phase System, "L_2 and L_3" Out

SHORTS. A short circuit is one in which a conductor makes contact at some point where it is not supposed to make contact. Generally speaking, there are two kinds of short circuits: direct shorts and cross shorts.

Direct Short. A direct short is caused by a positive lead coming in contact with a negative lead, or a black lead touching a white lead (in the case of a single-phase system) and there is not enough resistance between them. As you have already learned, this type of trouble causes blown fuses or tripped circuit breakers. (See figure 40.)

Cross Short. A cross short is contact between the positive leads of two independent circuits. (See figure 41.)

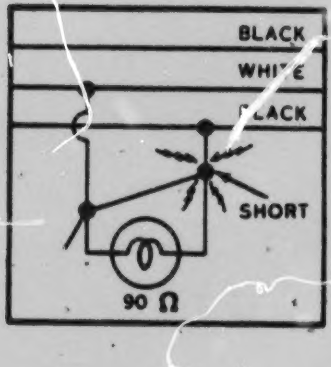


Figure 40. Direct Short

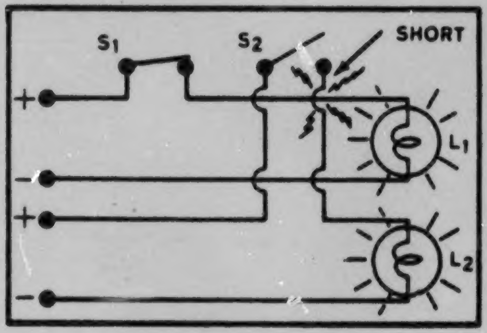


Figure 41. Positive to Positive Short

As you can see this short causes two independent units to operate from the same switch. In figure 41 even though S_2 is open, L_2 will burn. It burns because there is a complete path for current flow from the white wire through the lamp and to the black wire.

A switch or control device may be shorted. A shorted switch is one that fails to break contact when it is placed in the OFF position. This, naturally leaves the circuit without a control device. The effect of this is that the unit operates continuously. Figure 42 shows a shorted switch.

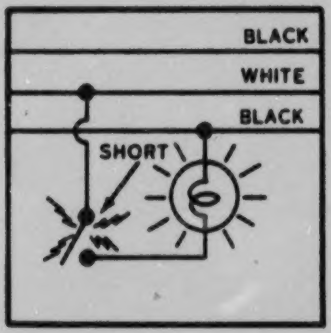


Figure 42. Short Across a Switch

300

LOW POWER. Low power causes units to operate improperly. Two effects are sluggish motors and dim lights. Besides low voltage from the power source, low power can be caused by loose, dirty, or corroded connections. Use a voltmeter to determine what the cause for low voltage is.

Location of Trouble

As soon as the type of trouble has been determined from the indication, the next step in troubleshooting is to select the correct testing device for the type of trouble to be located.

LOCATING OPENS. Opens may be located in circuits, where power can be left ON, with a voltmeter. Figure 43 shows voltmeter indications in a normal operating circuit.

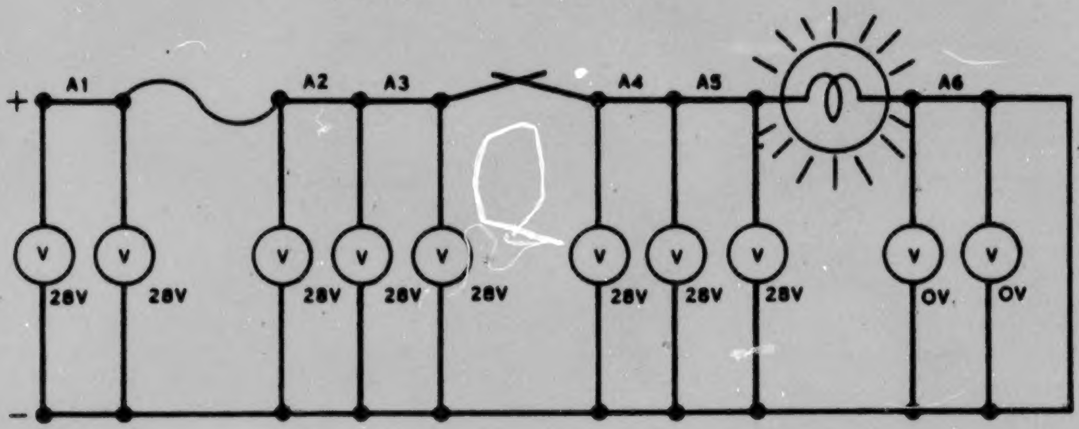


Figure 43. Normal Voltmeter Indications

In figure 44, the voltmeter indications show the location of the open to be in wire A-1. Exact location is determined between the normal and the abnormal indications.

A test light can be used in locating an open, using the same procedure as with the voltmeter. The main difference is that the test light does not indicate how much voltage.

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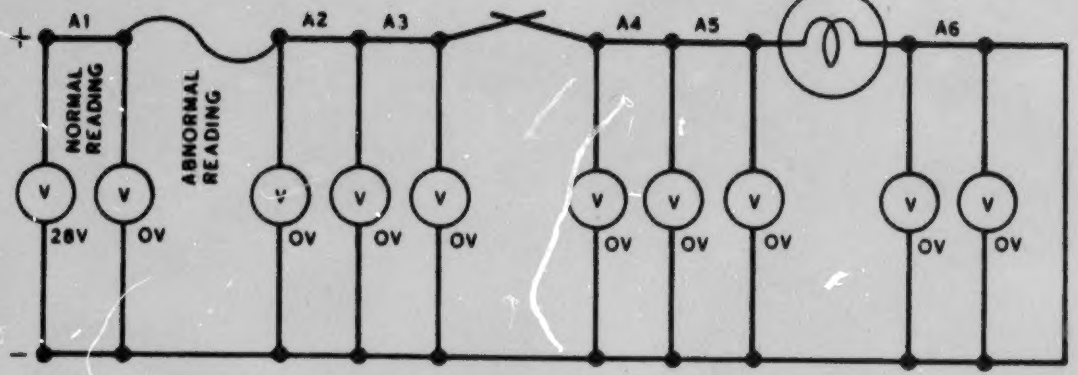
+
-
A1
A2
A3
A4
A5
A6
NORMAL READING
ABNORMAL READING
V
28V
OV

Figure 44. Locating an Open with a Voltmeter

Opens may be located with any device which will show continuity such as a continuity meter, continuity light, or ohmmeter. These testers are used when power is OFF in the circuit. Figure 45 shows an ohmmeter being used to locate an open in wire A-5.

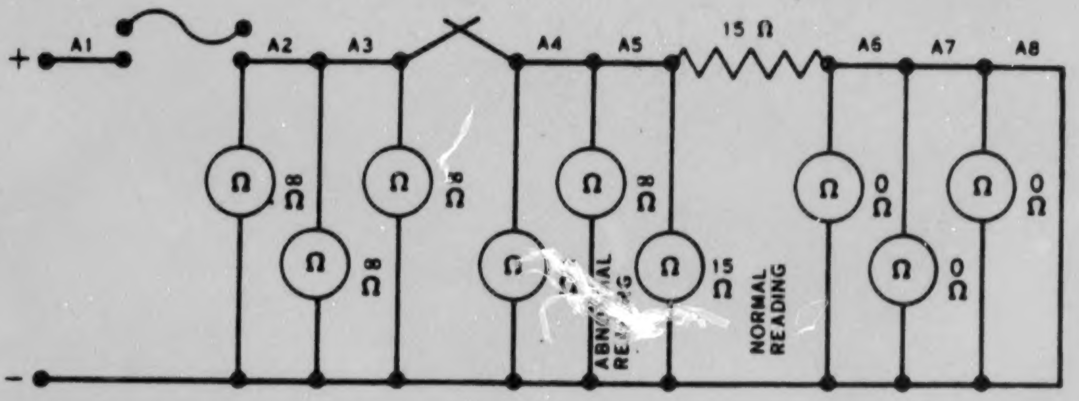
+
-
A1
A2
A3
A4
A5
15 Ω
A6
A7
A8
Ω
∞ Ω
15 Ω
0 Ω
ABNORMAL READING
NORMAL READING

Figure 45. Locating an Open with an Ohmmeter

LOCATING SHORTS. Testing devices which indicate continuity are usually used in locating shorts. A voltmeter cannot be used to locate cross shorts or direct shorts. Leads being checked for cross shorts or direct shorts are isolated. Figure 46 shows a direct short being located with an ohmmeter. Continuity has been found between positive wire, A-4, and the negative lead.

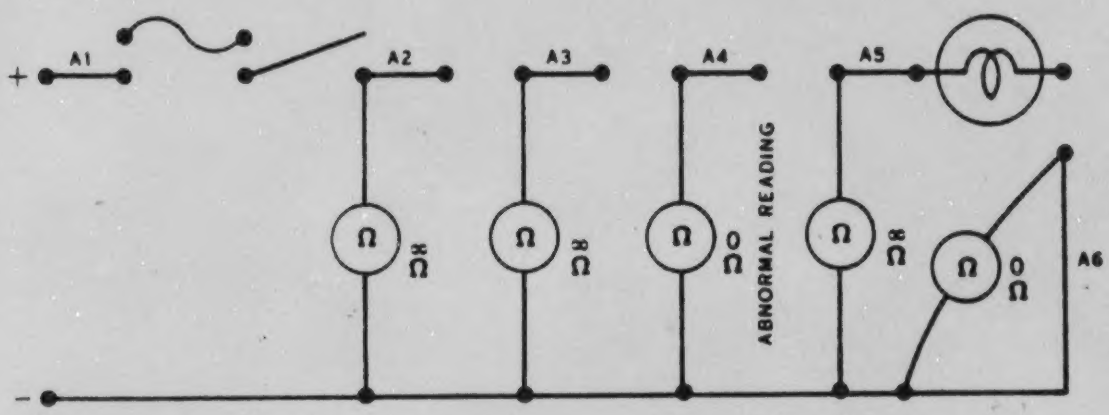

Figure 46. Locating a Direct Short with an Ohmmeter

Three-Phase, Four-Wire System

The same procedure is used to locate types of troubles in three and four-wire systems as in two-wire systems. The main point is to isolate the circuit being tested on the wiring diagram, select the correct testing device and proceed as in the two-wire system. For example, in figure 47, let us suppose that the transformer (primary winding) is the defective circuit. A voltage drop across the line between fuse at point "0" and top terminal at point "W" proves the wire to be open. There should be no difference in potential across these two points.

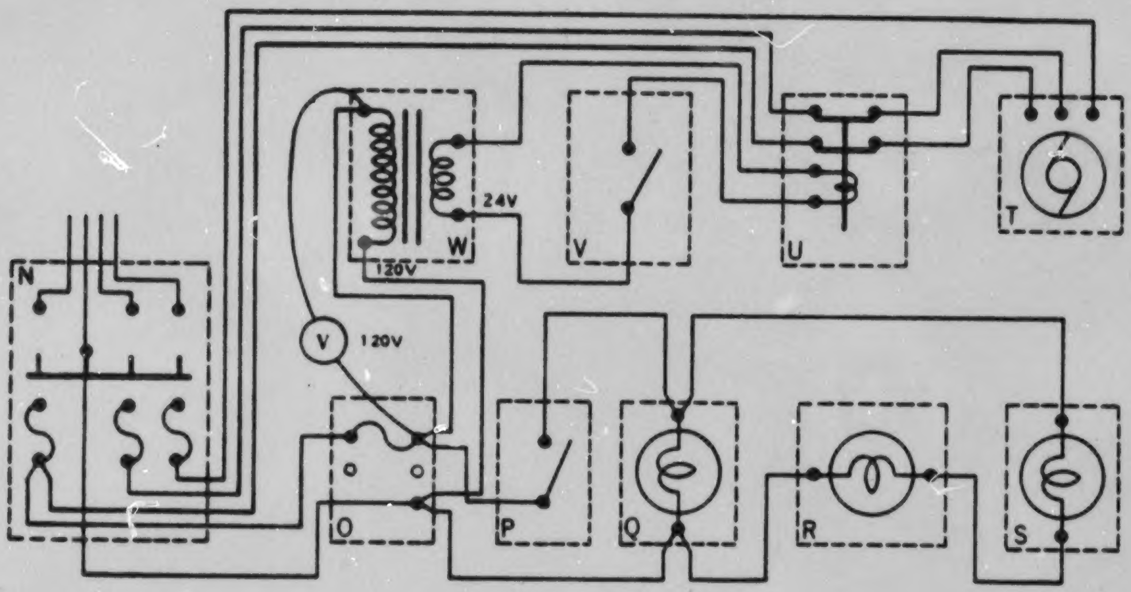

Figure 47. 208V 60 Cycle, 3-Phase

SUMMARY

A.C. troubleshooting is similar to d.c. troubleshooting. The same procedure is used for both.

Voltmeters, ohmmeters, continuity meters, continuity and test lights are used to find the exact location of the trouble.

Types of troubles are opens (preventing the flow of current), shorts (allowing current to flow where it is not desired), and low power (causing sluggish units).

QUESTIONS

1. What is the indication of an open circuit?

2. What is a positive to negative short called?

3. Which testing device can be used in circuits in which the power is ON?

4. Which testing device is used to locate a cross short?

5. What is the purpose of a wiring diagram?

REFERENCES

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2. Modern Refrigeration and Air Conditioning--Althouse and Turnquist.
3. Commercial and Industrial Refrigeration--Nelson
4. Electrical Manuals--Coyne.

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WORKBOOK 3ABR54530-II-2-P1 thru II-3-P4

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

ALTERNATING CURRENT WIRING SYSTEMS

May 1975

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II-3-P1	Troubleshooting Single-Phase 120-Volt Circuit	September 1974	28
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II-3-P4	Electrical Blueprint Reading and Trouble Analysis	May 1975	38

This supersedes WB 3ABR54530-II-2-P1 thru II-3-P4, September 1974.
Previous editions may be used.

Dept of Civil Engineering Training
Sheppard AFB, Texas

WB 3ABR54530-II-2-P1
September 1974

CHARACTERISTICS OF ALTERNATING CURRENT CIRCUITS

OBJECTIVE: To be able to check alternating current circuits for power.

1. A____________________causes inductive reactance in an ac circuit.

2. ____________________causes current to lag voltage in an ac circuit.

3. Draw the symbol for a coil.

4. Using a red pencil to represent voltage, and a blue pencil to represent current, show the relationship of current and voltage in an inductive circuit.

5. What is the letter symbol for inductive reactance?____________________

6. What is the opposition offered by inductance in the circuit called? (Figure 1)

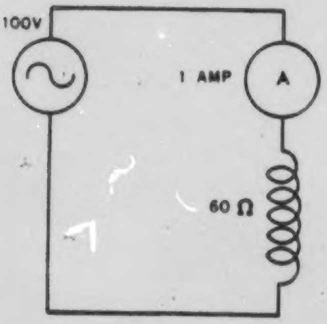


Figure 1

a. Total opposition is____________ ohms.

b. Resistance (measured) of the coil is____________ohms

7. A____________________causes capacitive reactance in an ac circuit.

8. ____________________causes current to lead voltage in an ac circuit.

9. Draw the symbol for a capacitor.

10. Using a red pencil to represent voltage, and a blue pencil to represent current, show the relationship of current and voltage in a capacitive circuit.

11. What is the letter symbol for capacitive reactance?____________________

12. What is the opposition offered by capacitance in the circuit called? (Figure 2)

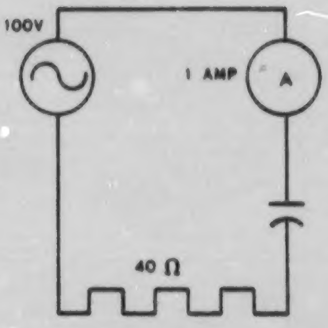

100V
1 AMP
A
40 Ω

Figure 2. Heater

a. Total opposition is______________ ohms.

b. Resistance (measured) of the heater is_______________ohms

13. What is the current flow in the circuit shown? (Figure 3)

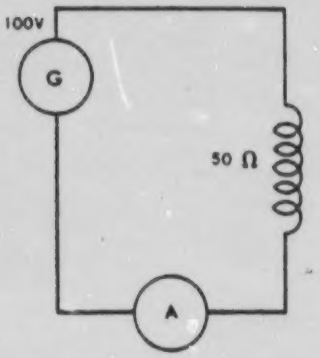


Figure 3

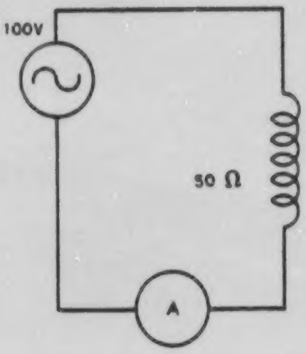


Figure 4

14. Will the current flow in this circuit (figure 4) be less than, more than, or equal to the current flow in problem 13?_______________

15. The ammeter will indicate__________amps for the circuit shown below (figure 5).

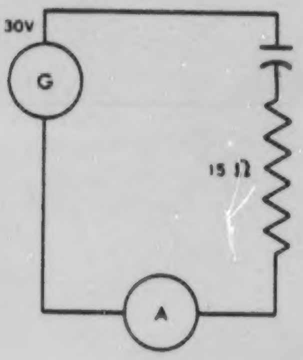


Figure 5

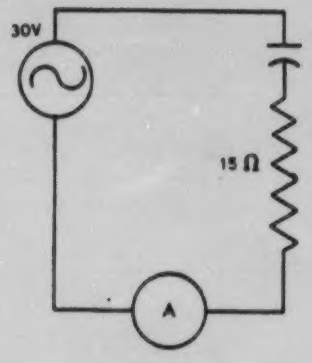


Figure 6

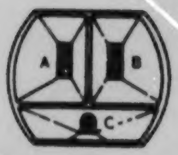
16. Will the current flow in this (figure 6) be more than, less than, or equal to, the current flow in problem 15 ?_______________________

Checked by_______________________
Instructor

CHECKING VOLTAGE ON THREE-PHASE TRANSFORMERS

OBJECTIVE: To determine types of transformer connections from voltmeter readings.

1.

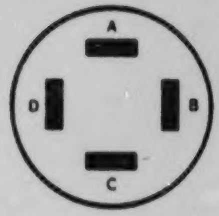


Which conductor is the neutral? ________

A - B = 120 volts
A - C = 120 volts
B - C = 0 volts

Figure 7

2.



Which conductor is the neutral? ________

A - B = 120 volts
A - C = 120 volts
A - D = 120 volts

B - C = 208 volts
C - D = 208 volts
B - D = 208 volts

Figure 8

Checked by ____________________
Instructor

MAKING PIGTAIL SPLICES

OBJECTIVE: To make a pigtail splice using a stripping tool.

1. Procure two pieces of scrap electrical wire (approximately 12-inches long).
2. Use the stripping tool and remove approximately 3 inches of the insulation from one end of each wire.
3. Cross the wires as illustrated in view A, figure 9.
4. Twist the wires as illustrated in view B, figure 9.

   NOTE: Be sure that both wires twist around each other.

5. Tighten the wires with a pair of pliers.

   NOTE: A pigtail splice should have at least five good tight turns.

6. Bend the ends back as illustrated in view C, figure 9.
7. Why is step 6 necessary?________

   ____

   ____

8. Have the instructor check your work.
9. Repeat this project as often as time permits.

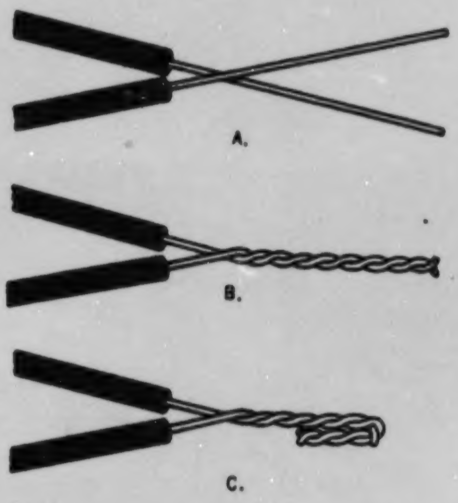


Figure 9. Pig[illegible]l Splice

Checked by______________________
Instructor

WIRING 220 VOLT, FOUR-WIRE SYSTEMS

OBJECTIVE: To be able to wire a four-wire 220-volt system.

INSTRUCTIONS

Use instructions given below.

CAUTION: Be sure the trainer is disconnected from the electrical power supply. All jewelry will be removed prior to starting this project. Rubber mats will be placed around trainers.

Wire 220-volt 3-phase, and 220-volt and 120-volt single-phase components.

Select wire and tools needed for job.

NOTE: Refer to figure 11 for trainer breakdown.

1. Locate the master switchbox and open it.
2. Remove the covers of junction box B, K, and C.
3. Remove cover from motor starter D and J.
4. Install a black and a red wire from master switchbox A through conduit to motor starter D.
5. Install a blue wire from master switchbox A to junction box B.
6. Install a blue wire from junction box B through conduit to motor starter D.
7. Remove lamp switch G and lampholder H.
8. Install a blue wire from junction box B to light switch G.
9. Install a blue wire from light switch G to lamp H.
10. Install a white wire from master switchbox A through conduit to lamp H.
11. Install a red and blue wire from master switchbox A through conduit to motor starter J.

Connecting the wires in master switchbox A.

1. Using wire strippers, strip 1/4 inch of insulation from the ends of each loose wire in master switchbox A.

2. Connect as follows:

    a. Black wire - Fuse #1
    b. White wire - Neutral Buss
    c. Red wires - Fuse #2
    d. Blue wires - Fuse #3

Connecting the wires in junction box B.

1. Using wire strippers, strip 3 inches of insulation from the ends of each loose wire in junction box B.

2. Pigtail the three blue wires (refer to figure 9, page 5).

3. Tape connection.

Connecting the wires in the lamp circuit.

1. Strip 1/4 inch of insulation from the ends of the wires at lamp switch G and lampholder H.

2. Using longnose pliers, make a loop in each stripped wire end.

3. Connect one blue wire to each side of lamp switch G.

4. Connect white wire to silver terminal of lampholder.

5. Connect blue wire to brass terminal of lampholder.

Connecting the wires at the motor starters.

1. Strip 1/4 inch of insulation from the ends of the wires at motor starters D and J.

2. Connect the wires at motor starter D as follows:

    a. Black wire - L1
    b. Red wire - L2
    c. Blue wire - L3

3. Motor Starter J

    a. Red wire - L1
    b. Blue wire - L2

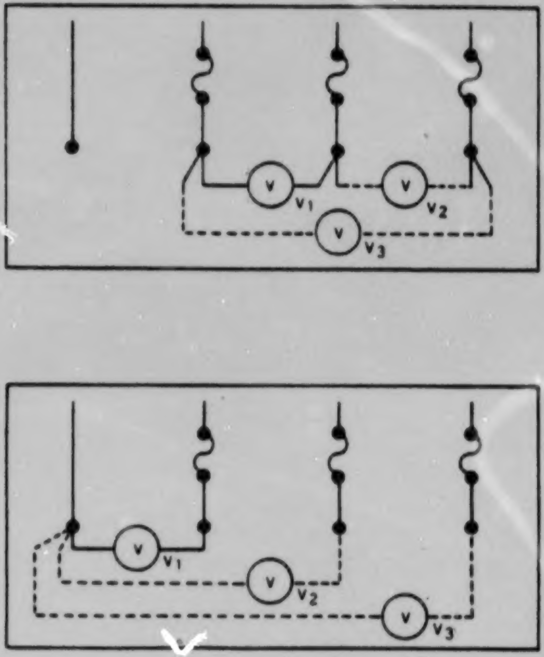
Checking the power supply

CAUTION: Remove jewelry. Stand on rubber mat. Keep hands off terminals. Remove tools, wire, etc. from the trainer.

1. Obtain a multimeter and set it to measure ac voltage

   CAUTION: Do not connect trainer to wall receptacle unless instructor is present.

2. Connect trainer to wall receptacle.
3. Turn the master switch on.
4. Place the voltmeter leads in the switchbox on the wires as shown in figure 10 and record the voltmeter readings in the blanks provided.



V_1 ______________________ volts

V_2 ______________________ volts

V_3 ______________________ volts

V_1 ______________________ volts

V_2 ______________________ volts

V_3 ______________________ volts

Figure 10. Master Switchbox

5. What is the voltage at motor starter D? ______________________

   volts __________ Ph.

6. What is the voltage at motor starter J? ______________ volts __________ Ph.
7. Turn on light switch G. Lamp should light?
8. Turn all switches off and disconnect the trainer from the wall receptacle.
9. Have the instructor check your voltage readings.

10. Return meter and tools to storage area.

11. Return rubber mats to storage table.

12. Clean your work area.

Checked by____________________________
Instructor

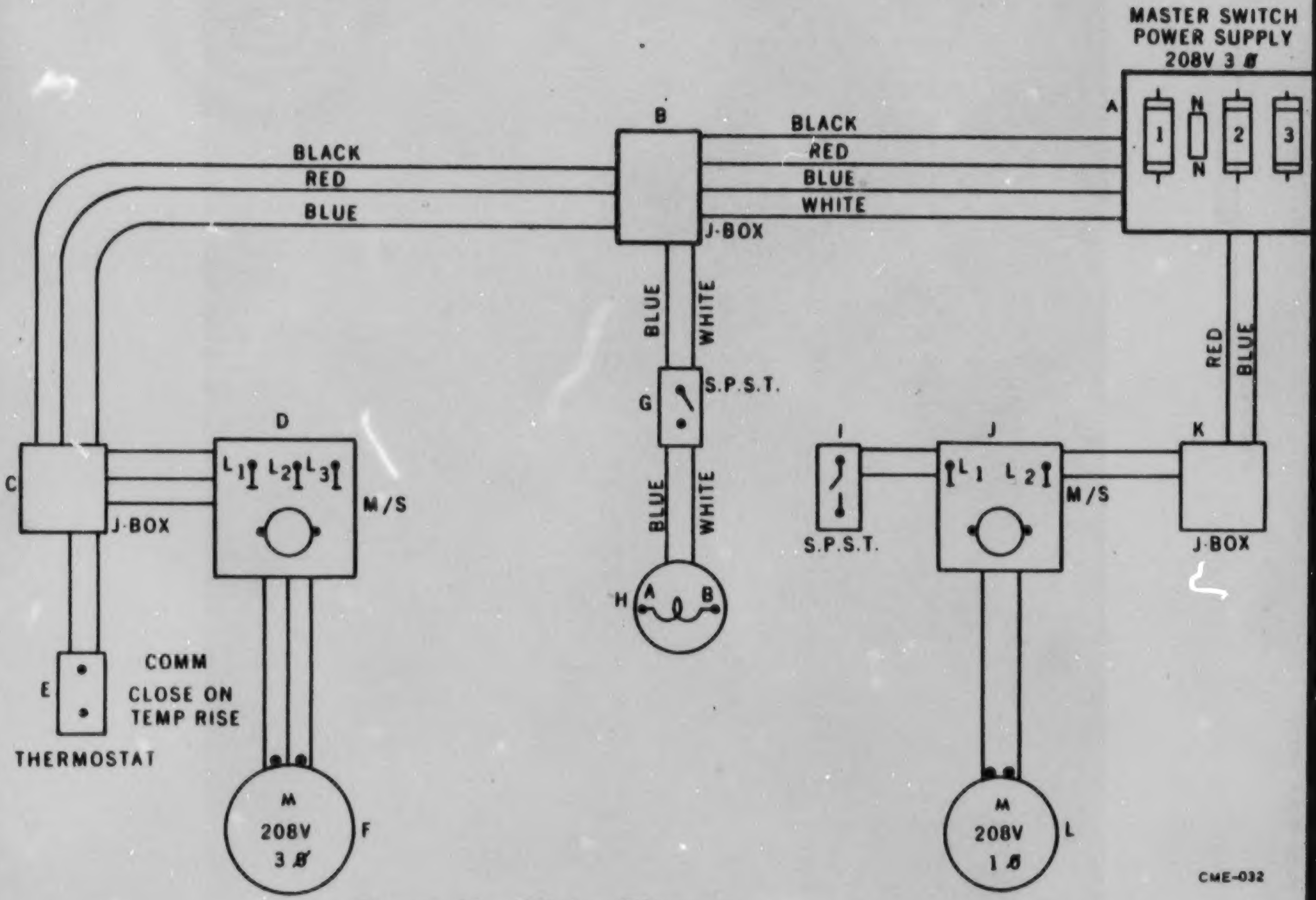

MASTER SWITCH
POWER SUPPLY
208V 3 Ø
A
1
N
N
2
3
B
BLACK
RED
BLUE
WHITE
J-BOX
BLACK
RED
BLUE
BLUE
WHITE
S.P.S.T.
G
BLUE
WHITE
H
A
B
RED
BLUE
K
J-BOX
J
L_1
L_2
M/S
I
S.P.S.T.
D
L_1
L_2
L_3
M/S
C
J-BOX
E
COMM
CLOSE ON
TEMP RISE
THERMOSTAT
M
208V
3 Ø
F
M
208V
1 Ø
L
CME-032

Figure 11. Wiring Diagram

WIRING THE ACROSS-THE-LINE MOTOR STARTER

OBJECTIVE:

To determine control and load circuits, to trace circuits, and to determine correct wiring procedures.

Motor Starters

1. What type motor starter is shown in figure 12? ______________________________
   (Do not list the manufacturer.)
2. Arrows have been drawn to various items on the drawing. Identify the item by placing its nomenclature in the blank.
3. Using your blue pencil, trace the CONTROL circuit on figure 12. Begin at L_1 and trace through the coil to L_2.
4. Have the instructor check your work.

Checked by ______________________________
Instructor

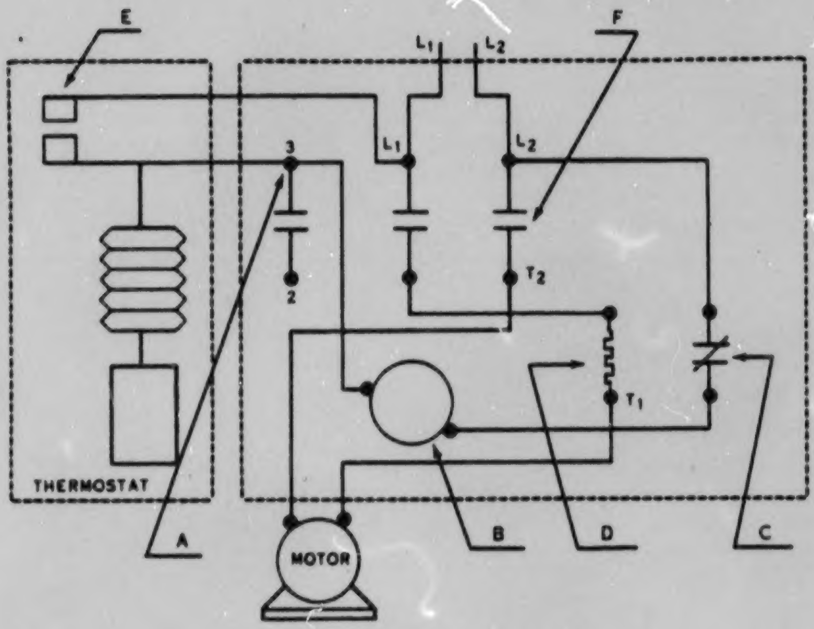


Figure 12. Single-Phase Across the Line Motor Starter

5. What type motor starter is shown in figure 13? ______________________
(Do not list the manufacturer.)

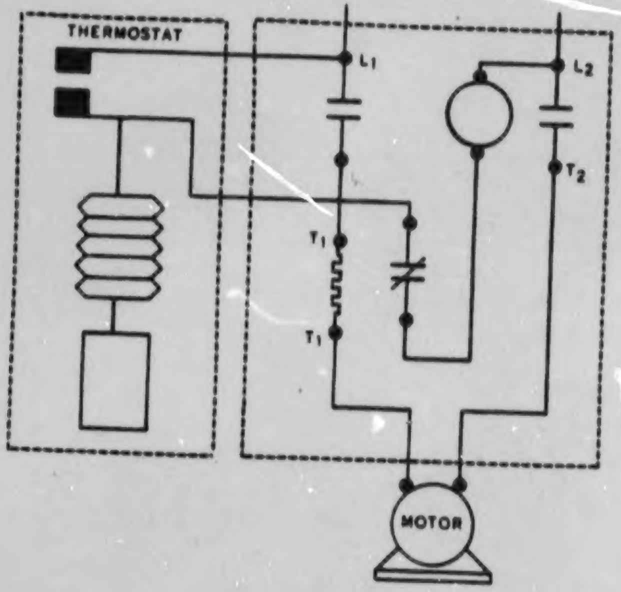


Figure 13. Single-Phase Across-the-Line Motor Starter

6. Using a red pencil, trace the LOAD circuit in figure 13. Assume that the contact points are closed. Begin with L_1 and trace through motor to L_2.

7. Have the instructor check your work.

Checked by______________________
Instructor

319

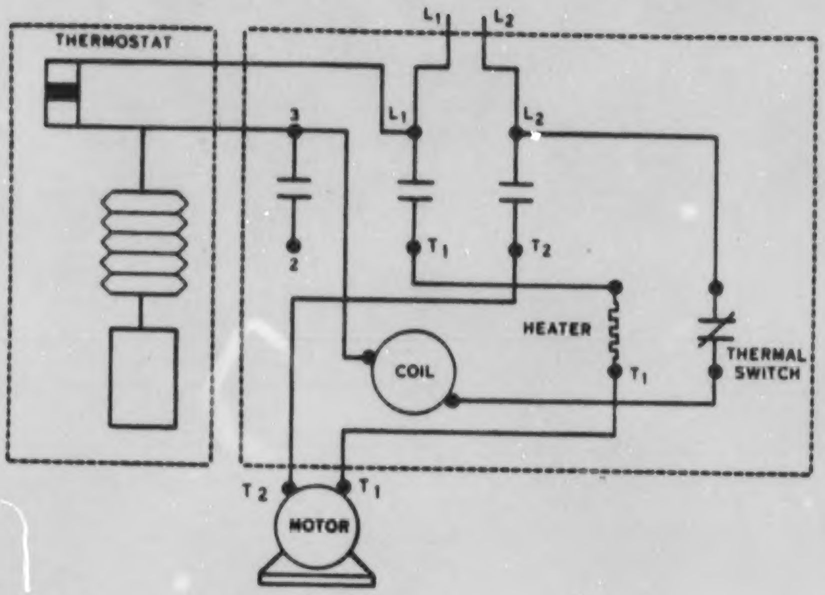

THERMOSTAT
L1
L2
3
L1
L2
T1
T2
2
HEATER
COIL
THERMAL SWITCH
T1
T2
T1
MOTOR

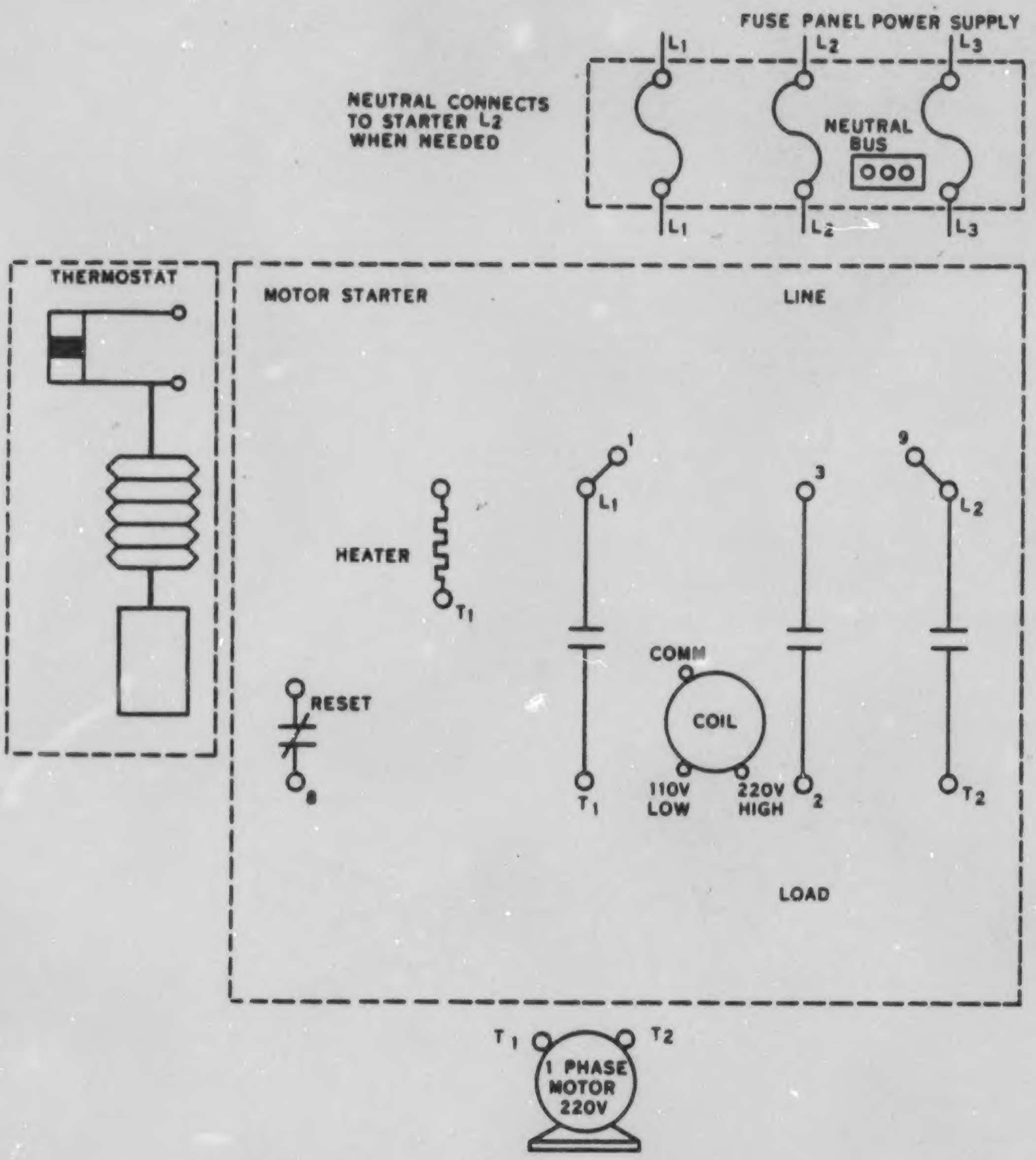
Figure 14. Single-Phase Across-the-Line Motor Starter

8. Using your red and blue pencil, in figures 14 and 15 trace the control circuit in blue and the load circuit in red.

9. Have the instructor check your work.

Checked by______________________
Instructor

320



FUSE PANEL POWER SUPPLY
L1
L2
L3
NEUTRAL CONNECTS TO STARTER L2 WHEN NEEDED
NEUTRAL BUS
L1
L2
L3
THERMOSTAT
MOTOR STARTER
LINE
1
9
3
L1
L2
HEATER
T1
COMM
COIL
RESET
8
T1
110V LOW
220V HIGH
2
T2
LOAD
T1
T2
1 PHASE MOTOR 220V

Figure 15. Single-Phase Across-the-Line Motor Starter

Three-Phase Motor Starters

1. Use figure 16 to complete the following.

   a. What type motor starter is shown? ______________________________
   (Do not list the manufacturer.)

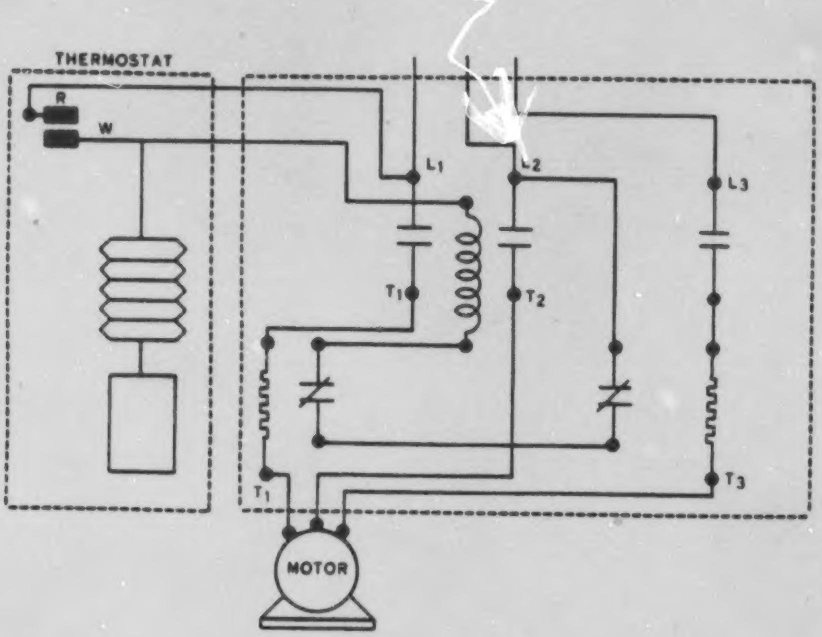


Figure 16. Three-Phase Across the Line Motor Starter

   b. To which line is the thermostat lead connected to in the motor starter?

   ____

   c. Draw the symbol for the coil. ______________________________

   d. Which circuit (control or load) is the coil in? ______________________

   e. Using a red pencil, trace the load circuit. Assume that the contact points are closed.

   f. How many lines must be used to have a complete load circuit for a three-phase motor? ______________________________

Checked by ______________________
Instructor

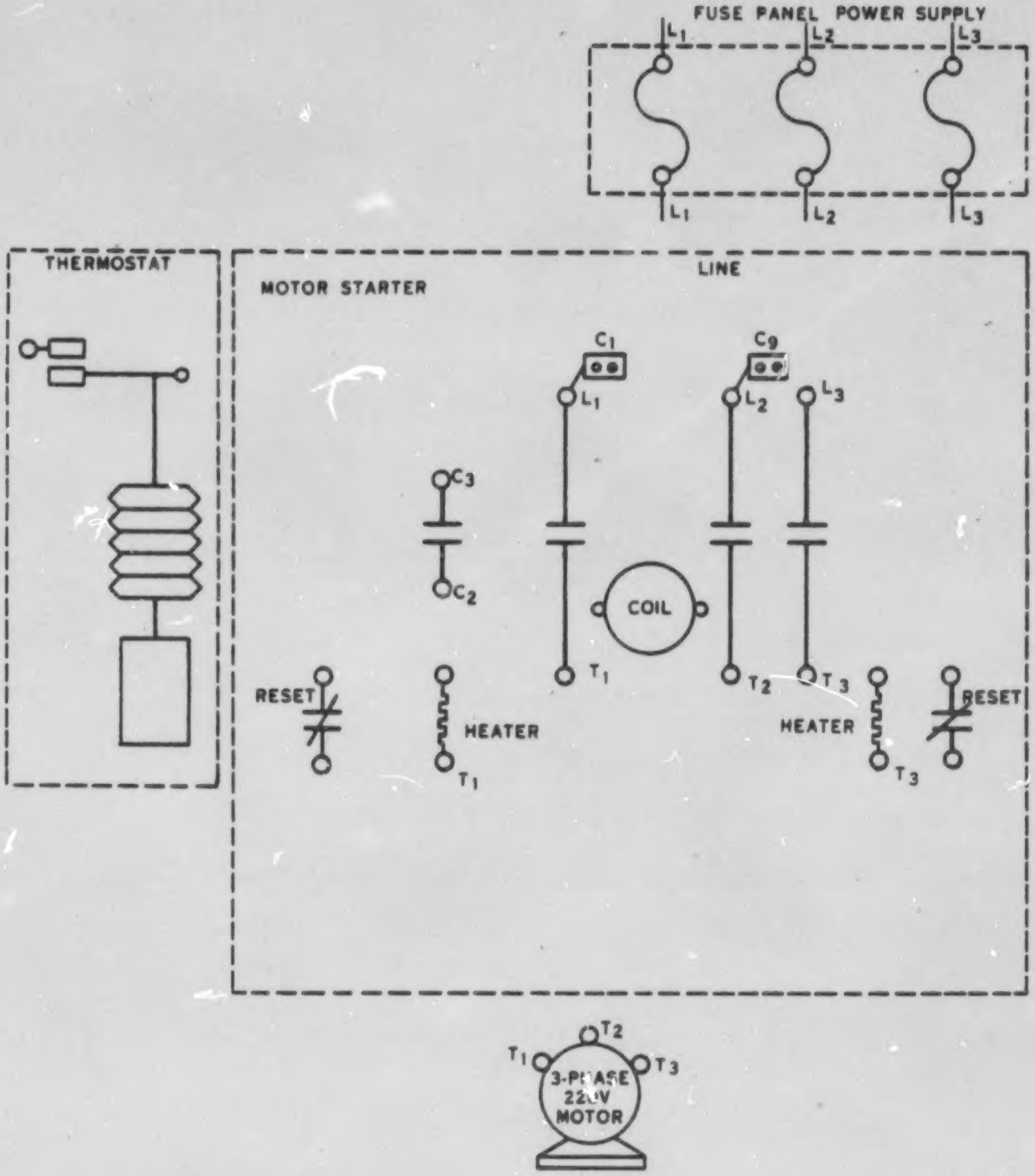

FUSE PANEL POWER SUPPLY
L1
L2
L3
L1
L2
L3
THERMOSTAT
LINE
MOTOR STARTER
C1
C9
L1
L2
L3
C3
C2
COIL
T1
T2
T3
RESET
HEATER
T1
HEATER
T3
RESET
T2
T1
T3
3-PHASE
220V
MOTOR

Figure 17. Three-Phase Across-the-Line Motor Starter

g. Using a blue pencil begin at L_1 and trace the control circuit.

h. Which circuit are the heaters (overloads) in?______________________________

i. Which circuit are the thermal switches in?________________________________

j. Why is the use of heaters necessary?_____________________________________

k. What causes the heaters (overloads) to heat up. ____________________________

l. How are the contacts of the thermal switches closed?_______________________

____

m. Have the instructor check your work.

Checked by__________________________
Instructor

2. Using your red and blue pencil, in figure 1[illegible], draw in the control circuit in blue and the load circuit in red.

3. Have the instructor check your work.

Checked by__________________________
Instructor

WIRING MOTOR STARTER CIRCUITS

INSTRUCTIONS:

Use instructions given below.

CAUTION: Be sure the trainer is disconnected from the electrical power supply. All jewelry will be removed prior to starting this project. Rubber mats will be placed around trainers.

Select wire and tools required for the job.

NOTE: Refer back to figure 11 for trainer breakdown.

1. Remove cover from thermostat E and switch I.
2. Install a black and a blue wire from motor starter D to thermostat E.
3. Install a blue and a red wire from switch I to motor starter J.
4. Using wire strippers, strip 1/4 inch of insulation from both ends of the four wires you installed.
5. Using longnose pliers, make a loop in the ends of wires located at thermostat E and switch I.
6. Connect one wire to each terminal of thermostat E and switch I.
7. Connect motor starter D as follows:
    a. Black wire________L_1
    b. Blue wire________right terminal of coil.
8. Connect motor starter J as follows:
    a. Blue wire________L_1
    b. Red wire________left terminal of coil.
9. Have instructor check your wiring.

NOTE: You have completed the first part of today's lesson. Do not put your tools away because you will be wiring the electric motors later today.

CAUTION: Do not connect your trainer to the electrical power supply.

Checked by____________________________
Instructor

WB 3ABR54530-II-2-P6
May 1975

OPERATING CHARACTERISTICS AND WIRING OF INDUCTION MOTORS

OBJECTIVE

To determine operating and electrical characteristics of motors and interpret information on motor data plates and wiring diagrams from motor starters.

Operating Characteristic of Electrical Motors

1. A four-pole motor operating on 60-cycle current has a magnetic slip of 50 rpm.
   - a. What is the synchronous speed of the motor? ______________________
   - b. What is the actual speed of the motor? ______________________
   - c. How fast will the motor operate under load on 50-cycle current? ______________________
   - d. Will the amperage increase or decrease? ______________________
2. How can you determine if a motor is designed for dual voltage operation? ______________________ ______________________ ______________________
3. If a motor starter formerly used on 60-cycle current cuts the motor off when a conversion to 50-cycle current is made, what should be done? ______________________ ______________________
4. A multiple speed motor has two, four, and six poles. What are the synchronous speeds of the motor when operating on 60-cycle current. Use the formula, $\text{rpm} - f \times 60 \times \frac{2}{NP}$.
5. In order to reverse the motor shown in figure 18, change leads ____________ ______________________ and ______________________

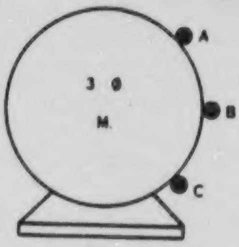


Figure 18

6. How would you connect the motor for high voltage operation? (Figure 19)

Connect A, ____________, and __________. NOTE: Dual voltage, single-phase motors use the same start winding for both high and low voltage operation.

B, ____________, __________,

____________, and __________.

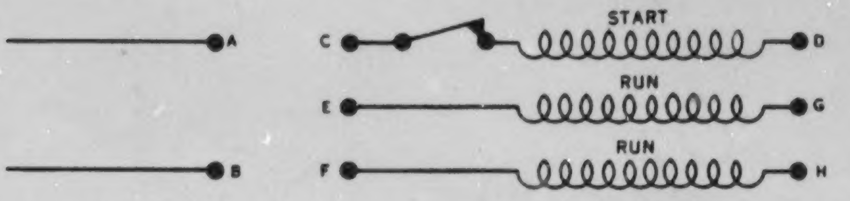


Figure 19

7. Place the following motors in sequence, starting with the motor having the poorest starting torque; and ending with the motor having the best starting torque; split-phase, synchronous, shaded pole, capacitor, and three phase.

Poorest starting torque ____

____

____

____

Best starting torque ____

8. A single-phase, 208-volt capacitor start motor will not start. An ohmmeter check of the capacitor is made, with the results, as shown in figure 20. What should the repairman do? ____________________

____

____

____

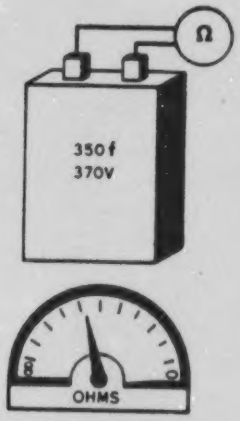


Figure 20

Checked by ______________________
Instructor

INTERPRETATION OF INFORMATION ON MOTOR DATA PLATE

Information: The data plate of a motor reads as follows: Voltage - 220/440; Frequency -60 cps; Amps -7.2/3.6; rpm - 1150; Phase - 3Ø; hp - 1/2. Unless otherwise stated, the motor is operating on 440 volts.

1. How many poles does the motor have? ____________________

2. What is the minimum wire size for the motor? ____________________
(Use charts on page 11 of dc study guide.)

3. What size fuses should be used? ____________________

4. How many wires will be required? ____________________

5. The motor is to be controlled by a motor starter. You are to select the proper heater for the motor starter. Use the following table:

Heater No.	F. L. Amps	Heater No.	F. L. Amps	Heater No.	F. L. Amps
1	.2 - .8	6	3.5 - 3.9	11	7.4 - 7.9
2	.9 - 1.4	7	4.0 - 4.6	12	8.0 - 8.6
3	1.5 - 2.0	8	4.7 - 5.5	13	8.7 - 9.3
4	2.1 - 2.7	9	5.6 - 6.3	14	9.4 - 9.7
5	2.8 - 3.4	10	6.4 - 7.3	15	9.8 - 10.0

6. The proper heater for 440-volt operation of the motor is No. ____________________

7. How many heaters are required for this application? ____________________

8. What is the proper heater number for 220-volt operation? ____________________

9. The holding coil of the motor starter (figure 21) is to operate at the same voltage (440 volts) as the motor. Which terminals should be used?

____

10. A thermostat is to be used to control the motor starter. The contacts of the thermostat will be connected in the ____________________

____

____

circuit.

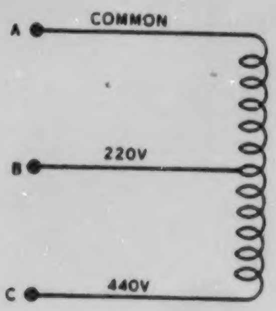


Figure 21

11. When operating on 440 volts, the coils of the motor will be connected in (choose one) (series) (parallel).

12. The motor starter is located in an equipment room where the ambient temperature is quite high. The coil is connected for 440-volt operation. The motor stops on overload occasionally, but a recording ammeter records a maximum of 3.5 amps. What should be done to keep the motor operating?______________________________

____

Checked by___________________________
Instructor

WIRING 1 Φ INDUCTION MOTORS

1. Using the data plate information and symbols available in figure 22, connect the motor to the power supply using the across-the-line motor starter and thermostat to control the operation of the motor.

2. Connect the motor to rotate clockwise.

3. Use red pencil to draw load circuit and blue pencil to draw the control circuit.

4. What size heater will be used for the motor?___________________________________
(Use table on page 21.)

5. How many hot leads are needed to operate the motor?___________________________

6. What size wire should be used?____
(Use chart on page 11 of dc study guide.)

7. The coil is connected in what circuit?____

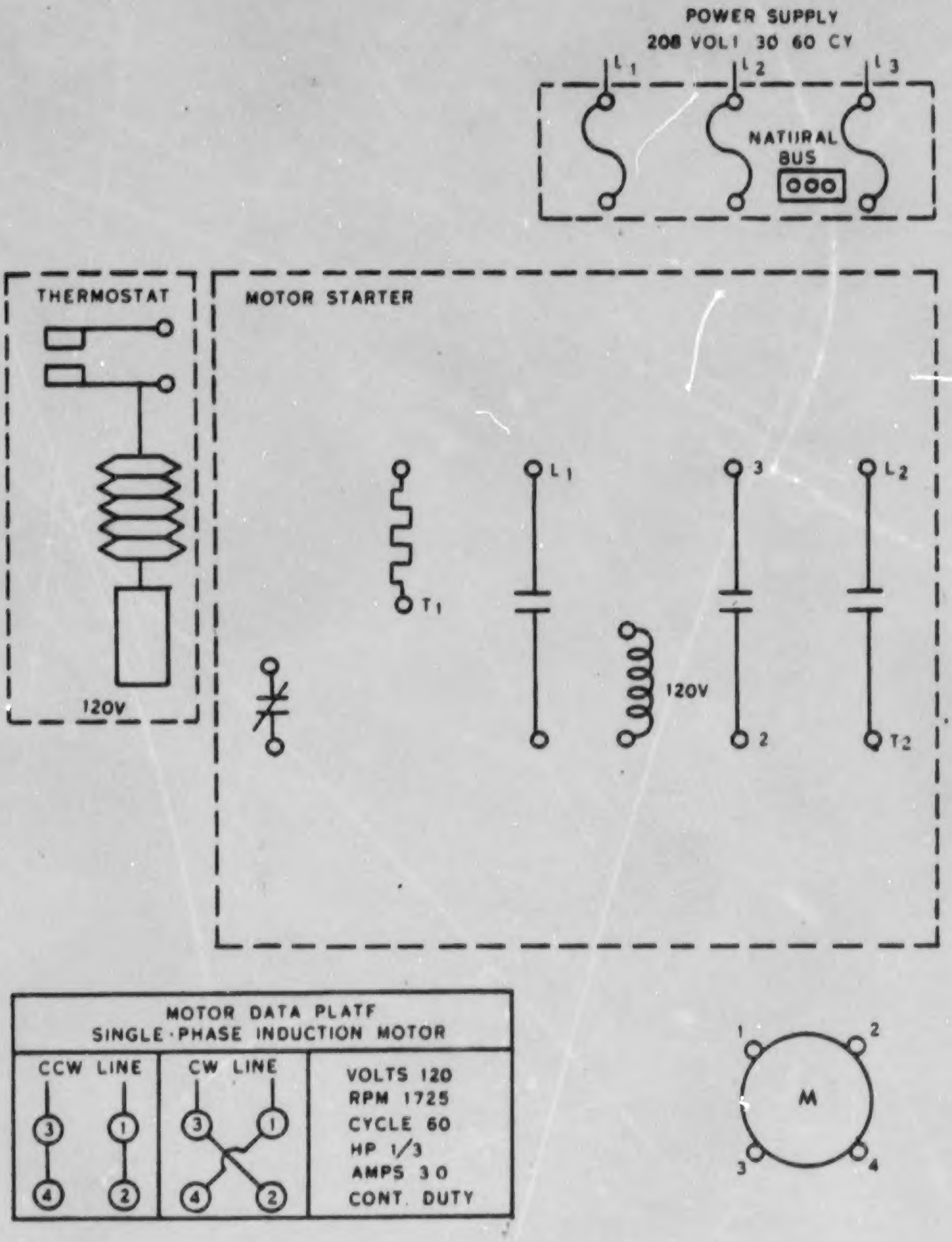

POWER SUPPLY
208 VOLT 30 60 CY
L1
L2
L3
NATURAL BUS
THERMOSTAT
120V
MOTOR STARTER
T1
L1
3
L2
120V
2
T2
MOTOR DATA PLATF
SINGLE-PHASE INDUCTION MOTOR
CCW LINE
CW LINE
3
1
4
2
VOLTS 120
RPM 1725
CYCLE 60
HP 1/3
AMPS 3.0
CONT. DUTY
1
2
3
4
M

Figure 22

WIRING 3 Ø INDUCTION MOTOR

1. Using the information and symbols available in figure 23, connect the motor to the power supply using the across-the-line motor starter and thermostat to control the operation of the motor.

2. Use red pencil to draw load circuit and blue pencil to draw the control circuit.

3. What size heater will be used for the motor? ______________________________
(Use table on page 21.)

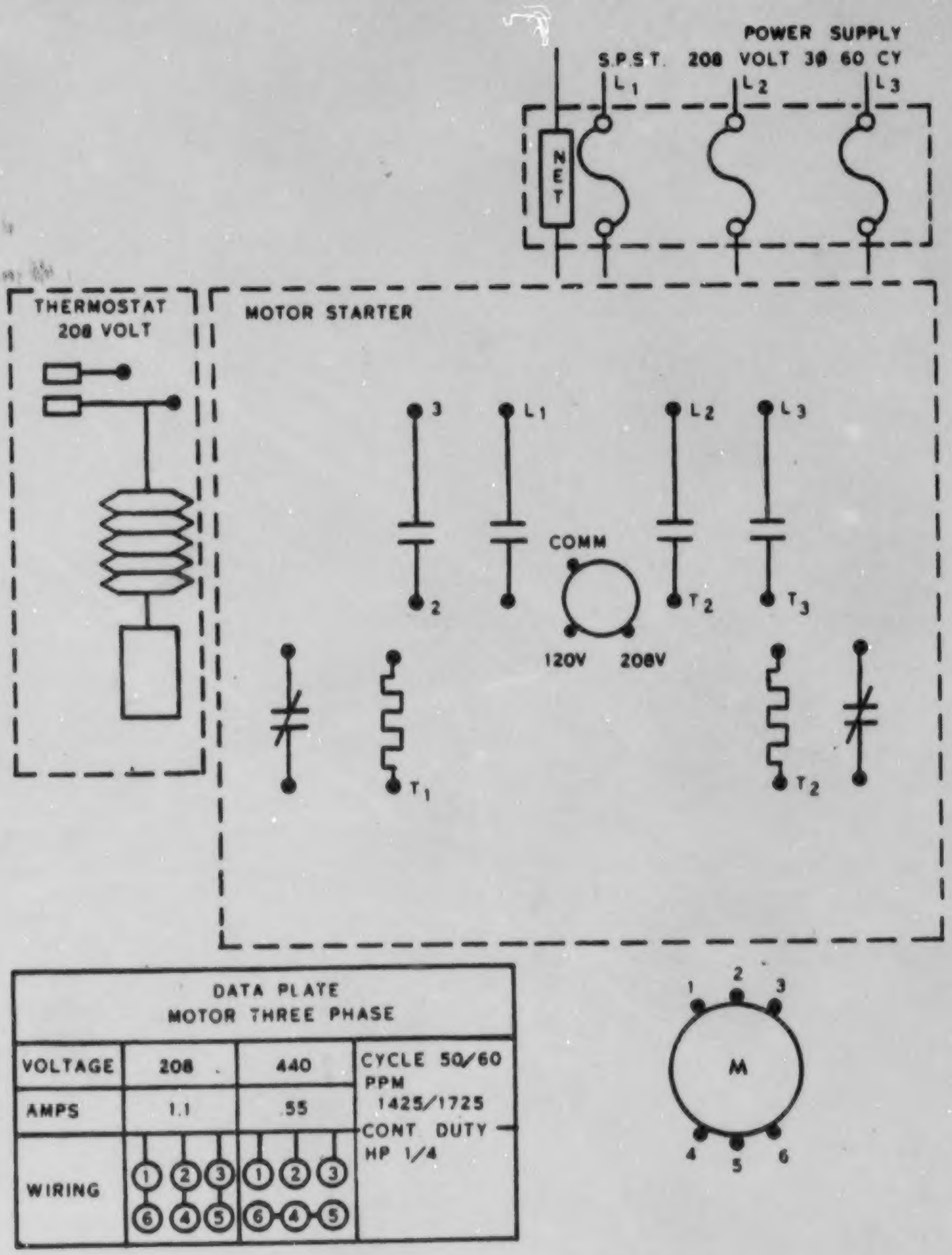
4. How many hot leads are needed to operate the motor? ________________________

____

5. The coil is connected in what circuit? ____________________________________

6. The direction of rotation can be changed by changing what terminal leads?

____


POWER SUPPLY
S.P.S.T.
208 VOLT 3Ø 60 CY
L1
L2
L3
NET
THERMOSTAT
208 VOLT
MOTOR STARTER
3
L1
L2
L3
2
COMM
T2
T3
120V
208V
T1
T2
1
2
3
M
4
5
6

DATA PLATE MOTOR THREE PHASE			
VOLTAGE	208	440	CYCLE 50/60 RPM 1425/1725 CONT DUTY HP 1/4
AMPS	1.1	.55	
WIRING	① ② ③ ⑥ ④ ⑤	① ② ③ ⑥-④-⑤	

Figure 23

WIRING MOTOR CIRCUITS

INSTRUCTIONS

Use instructions given below.

CAUTION: Be sure the trainer is disconnected from the electrical power supply. All jewelry will be removed prior to starting this project. Rubber mats will be placed around trainers.

1. Using wire strippers, strip 1/4 inch of insulation from the ends of the three wires at motor starter D.
2. Connect one wire to the outlet of each heater on motor starter D. (T_1 and T_3)
3. Connect the remaining wire to terminal T_2 of motor starter D.
4. Strip 1/4 inch of insulation from the ends of the two wires at motor starter J.
5. Connect one wire to heater outlet on motor starter J. (T_1)
6. Connect the other wire to terminal T_2 of motor starter J.
7. Check all connections with an ohmmeter to ensure no grounding of circuits.
8. Trace circuits with ohmmeter to ensure their completion. Have instructor check your work.

   CAUTION: Do not plug trainers into the power supply until instructed to do so by the instructor.

9. When directed by the instructor, plug in trainer and turn on power.
10. Check all circuits by energizing control circuits for operation of motors.
11. Check power supply in main power supply box (TPST SW) with voltmeter set in the 400V ac range. Record readings in blanks provided below:

    fuses #1 to 2 __________ fuses 2 to 3 __________ fuses 1 to 3 __________

12. Check power supply at line side of 3Ø motor starter using voltmeter on 400V ac and record readings in blanks provided:

    line 1 to 2 __________ line 2 to 3 __________ line 1 to 3 __________

13. Check power supply at line side of 1Ø motor starter using voltmeter on 400V ac and record readings in blanks provided: line 1 to 2 __________

14. Turn off control circuits, main power, and unplug trainer.
15. Remove all wiring from the trainer that you have installed.
16. Replace tools to proper storage area and clean your area by placing wire in scrap wire container, replace rubber mat and sweep your trainer area.

Checked by__________________________
Instructor

TROUBLESHOOTING SINGLE-PHASE 120-VOLT CIRCUIT

OBJECTIVE:

To determine location of troubles and to analyze electrical circuits using diagrams.

Analyzing Electrical Circuits Using a Diagram

1. The wires on the diagram in figure 24 have been numbered 1 through 7. By each numbered wire below, list the unit by letter that would be inoperative if that specific wire were open. (Study the diagram carefully.)

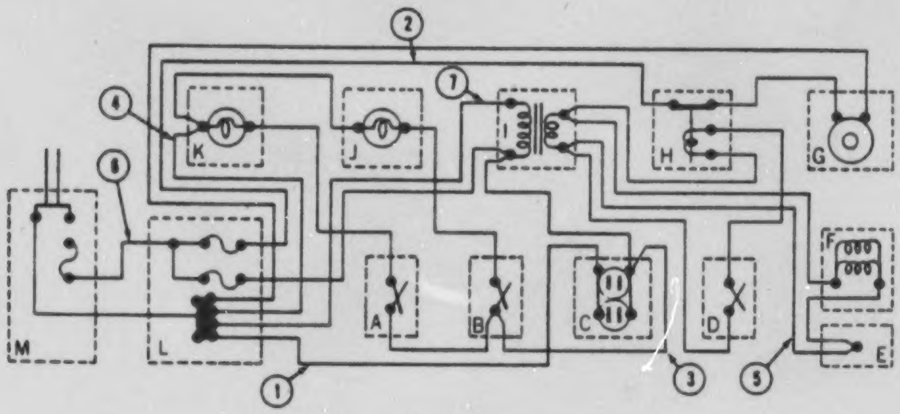


Figure 24. 120 V Single Phase

WIRE NUMBER	INOPERATIVE UNITS
1	
2	
3	
4	
5	
6	
7	

Determining Location of Troubles by Use of Meters

1. Note that the diagram you have been studying is also the diagram of the trainer assigned to you by the instructor.

   NOTE: Use only the top half, 120-volt part, of the trainer.

2. Be sure that all control devices are in the OFF position.
3. Be sure that the trouble switches at the right end of the trainer are in the OFF position.
4. Connect the trainer to the wall receptacle.
5. Turn the switchbox at the end of the trainer ON.
6. Turn the 120 V switchbox ON.
7. Make an operational check of all the units.

   NOTE: If there is a malfunction in the trainer, report it to the instructor.

8. Obtain a multimeter to be used in locating the trouble.
9. Start your troubleshooting by turning trouble switch No. 1 (on the right end of the trainer) ON.

10. Operate all circuits to determine the defective circuit.

   a. What is the type of trouble?______________________________

   b. Where is it located?______________________________

   c. What meter did you use to find its location?________________________

11. Turn No. 1 OFF. Turn No. 2 ON. Operate all circuits. Proceed with your troubleshooting. Fill in the blanks.

TROUBLE SWITCH	TYPE OF TROUBLE	LOCATION	METER USED
2			
3			
4			
5			
6			

12. Turn all switches OFF and disconnect trainer from wall receptacle.

Checked by________________________
Instructor

TROUBLESHOOTING THREE-PHASE CIRCUITS

OBJECTIVE:

To use electrical meters to determine location of trouble and analyze electrical circuits by using diagrams.

Analyzing Electrical Circuits Using a Diagram and Meters

1. The wires on the diagram in figure 25 have been numbered 1 through 5. Beside each wire number in the spaces below, list the unit by letter that would be inoperative if that specific wire were open.

WIRE NUMBER	INOPERATIVE UNITS
1	
2	
3	
4	
5	

2. Note that the diagram in figure 25 is that of the trainer assigned to you by the instructor.

3. Be sure all control devices are in the OFF position.

4. Be sure all trouble switches at the right end of the trainer are in the OFF position.

5. Connect the trainer to the wall receptacle.

6. Turn the switch box at the end of the trainer ON.

7. Turn the 208 V switch box ON. (Only the bottom half of the trainer 208-V part is to be used.)

8. Make an operational check of all the units. If there is a malfunction in the trainer, report it to the instructor.

9. Obtain a multimeter to be used in locating the troubles.

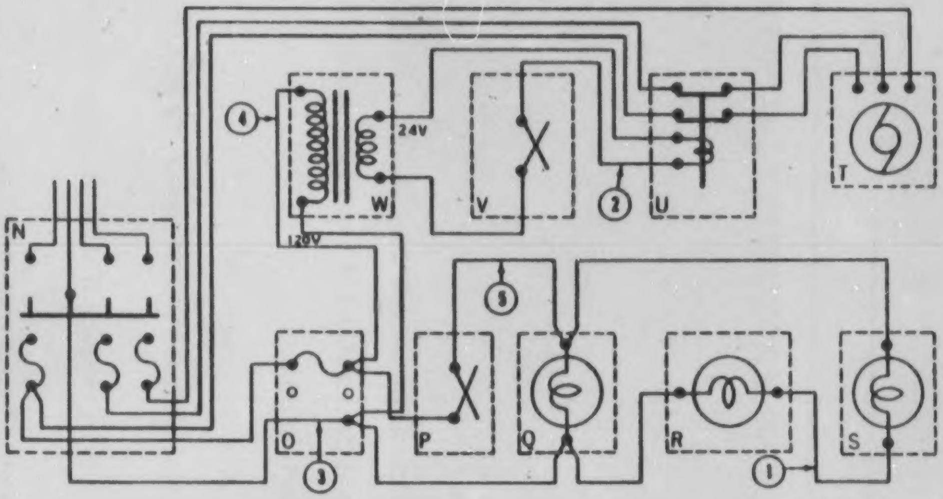

④
24V
W
V
②
U
T
N
120V
⑤
O
P
Q
R
S
③
①

Figure 25. 208-V 60-Cycle, 3-Phase

10. Start your troubleshooting by turning trouble switch No. 7 (on the right end of the trainer) ON. Operate all circuits to determine the defective circuit.

    a. What is the type of trouble? ______________________________

    b. Where is it located? ______________________________

    c. What meter did you use to find its location? ______________________________

11. Turn switch No. 7 OFF. Turn switch No. 8 ON. Operate all circuits. Proceed with your troubleshooting. Fill in the blanks below.

TROUBLE SWITCH	TYPES OF TROUBLE	LOCATION	METER USED
8			
9			
10			
11			
12			

12. Turn all switches OFF and disconnect the trainer from the wall receptacle.

Checked by ______________________________
Instructor

WB 3ABR54530-II-3-P3
September 1974

TROUBLESHOOTING 208-VOLT SINGLE-PHASE CIRCUITS

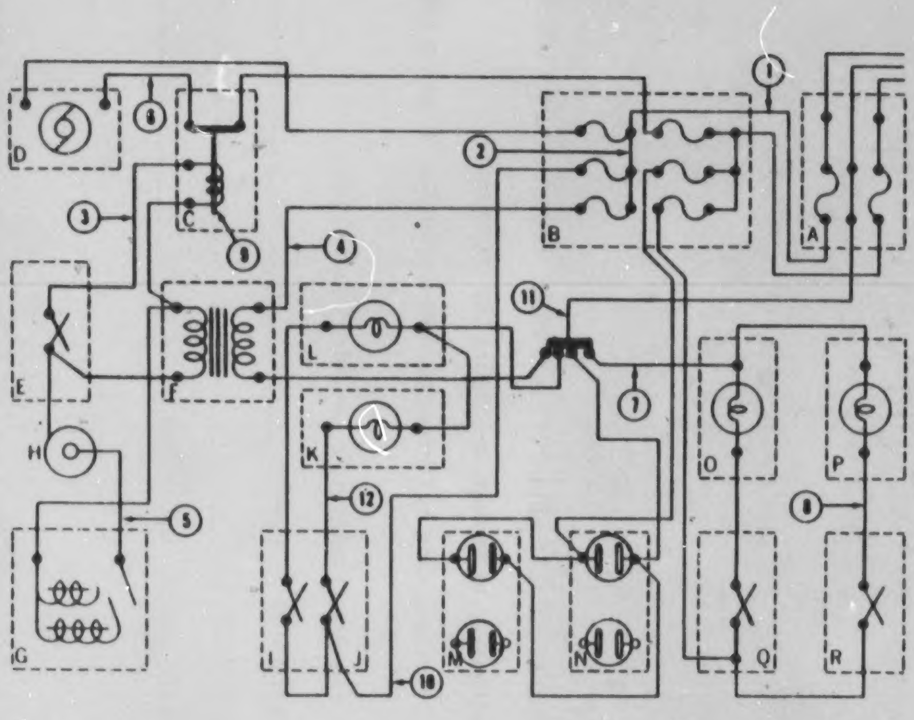
OBJECTIVE:

To use electrical meters to determine trouble in 208-volt single-phase circuits and analyze electrical circuits by using diagrams.

Analyzing Electrical Circuits Using a Diagram

1. The wires on the diagram in figure 26 have been numbered 1 through 12. By each numbered wire in the spaces below, list the unit or units by letter, that would be inoperative if that specific wire were open. (Study the diagram carefully.)

WIRE NO	INOPERATIVE UNITS
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	



1
2
3
4
5
6
7
8
9
10
11
12
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R

Figure 26. 208-V, 60-Cycle, Single-Phase Circuit

Determining Location of Troubles by Use of Meters

1. Note that the diagram you have been studying is also the diagram of the trainer assigned to you by the instructor.

   NOTE: Use only the 208-V, single-phase part of the trainer.

2. Be sure all control devices are in the OFF position.
3. Be sure all the trouble switches at the right end of the trainers are in the OFF position.
4. Connect the trainer to the wall receptacle.
5. Turn the switchbox at the end of the trainer ON.
6. Turn the 208-V, single-phase, switch box ON.
7. Make an operational check of all the units.

   NOTE: If there is a malfunction in the trainer, report it to the instructor.

8. Obtain a multimeter to be used in locating the troubles.
9. Start your troubleshooting by turning trouble switch No. 2 (on the right end of the trainer) ON.
10. Operate all circuits to determine the defective circuit.
    a. What is the type of trouble?______________________________
    b. Where is it located?______________________________
    c. What meter did you use to find its location?____________________

11. Turn No. 2 OFF. Turn No. 3 ON. Operate all circuits. Proceed with your troubleshooting. Fill in the blanks below.

TROUBLE SWITCH	TYPE OF TROUBLE	LOCATION	METER USED
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

12. Turn all switches OFF and disconnect trainer from wall receptacle.

Checked by________________________
Instructor

ELECTRICAL BLUEPRINT READING AND TROUBLE ANALYSIS

OBJECTIVE:

To be able to know the characteristics of voltage, current, and resistance in circuits.

Determine voltage drops, currents, and resistances.

Use Ohm's Law to determine currents and resistances.

Review of Circuit Characteristics

1. Answer the following questions as a review of circuit characteristics taught in Day 8. Fill in the blanks with the words. VOLTAGE, CURRENT, or RESISTANCE.

   a. In a series circuit, ______________ remains the same.

   b. In a parallel circuit, ______________ remains the same.

   c. In a parallel circuit, ______________ can be added.

   d. ____________________________ causes voltage drop.

   e. In a parallel circuit, total ________________________________ must be smaller than that of the smallest unit.

   f. In a series circuit, ______________ and ________________________ can be added to find totals, but in a parallel circuit only ________________________ can be added.

   g. To find total resistance in any circuit, divide total voltage by total ____

2. Use information in figure 27 to answer the following questions.

   a. The voltage drop across the primary coil in Unit W should be ______________ ______________________ volts.

   b. Current flow through light Q is ______________________ Amps.

   c. Current flow through light S is ______________________ Amps.

   d. Voltage drop across light S is ______________________ volts because it is wired in ________________________ to light R.

   e. Voltage drop across the coil in Unit U should be ____________________ volts.

NOTE: Now that you have reviewed circuit characteristics and traced circuits in order to answer the questions in step 2, you are ready to fill in the blanks on the next page.

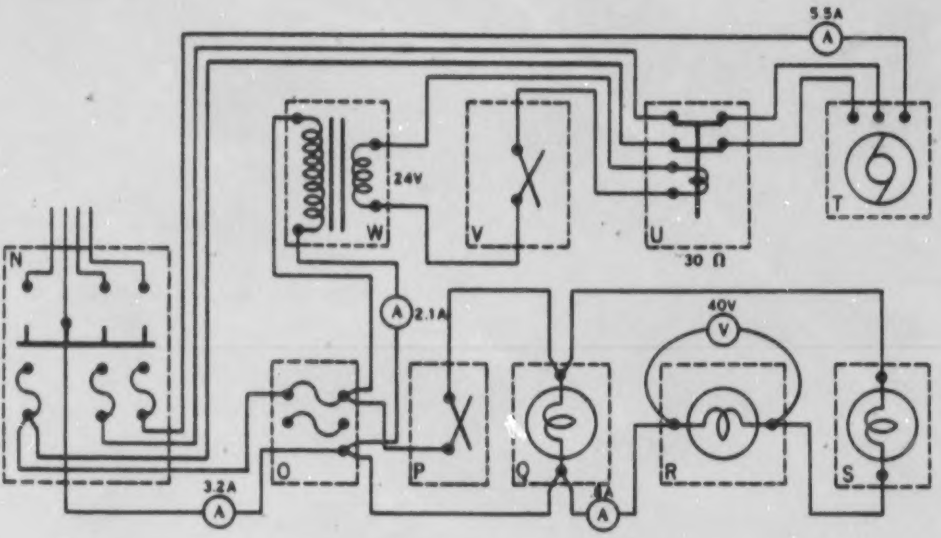


Figure 27. 208-V, 60-Cycle, 3-Phase

Using Ohm's Law and Circuit Characteristics to Determine Unknown Factors in 208-V 3-Phase System

1. List in the appropriate blanks in the chart on next page, all voltages, currents, and resistances which are given in figure 27.

2. Determine the unknown factors for each unit of resistance either by using circuit characteristics or by using Ohm's Law.

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UNIT	E	I	R
Q			
R			
S			
W (Primary Coil)			
U (Coil)			
T			

Using Ohm's Law and Circuit Characteristics in 208-V, Single-Phase

1. Use information in figure 28 and circuit characteristics to answer the following questions.

   a. Units C and G are in what type circuit? (Series, Parallel)____________

   b. Current flow through the coil in Unit C is________________

   c. Current flow through unit K is____________________

   d. The voltage drop across the coil in Unit C is____________volts.

   e. Current flow to lights O and P is__________________

   f. Total current flow in the 120 V system is______________

   g. Voltage drop across unit D is____________________

   h. Voltage drop across unit M is____________________

   i. Resistance of coil in unit C is__________________ohms.

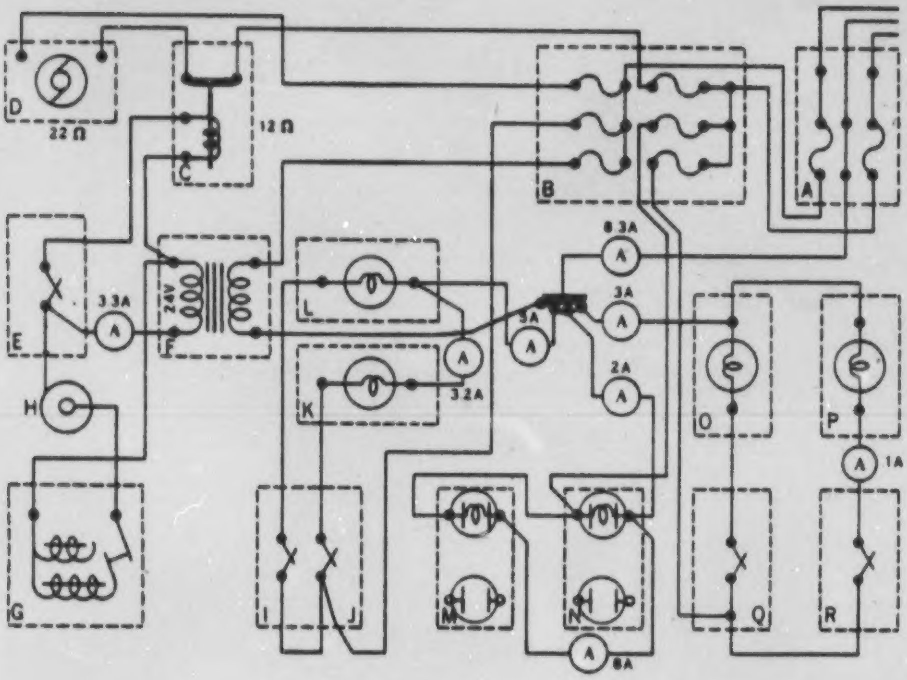
D
22 Ω
C
12 Ω
B
A
E
3.3A
24V
F
L
K
3.2A
8.3A
3A
5A
2A
O
P
1A
H
G
I
J
M
N
Q
R
8A

Figure 28. 208-V, 60-Cycle, Single-Phase Circuit

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2. Determine the unknown factors for each unit of resistance either by using Ohm's Law or by using circuit characteristics.

UNIT	E	I	R
C			
D			
F (Primary Coil)			
G			
K			
L			
M			
N			
O			
P			

355.

ATC-SHEPPARD AFB TEX. 73-1480

THE MAN

2TPT-3100-06

Technical Training

TROUBLESHOOTING

Opens - Shorts - Grounds - and Low Power

July 1969

11-6

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

VALIDATION DATA

This programmed text has been validated on 53 students enrolled in ABR 54330 Electrical Power Production Course.

The Criterion Examination has a total of 24 responses with 20 out of 24 being the standard of performance. Twenty correct responses is 100%.

The following results indicate time taken to complete the text and scores obtained on the Criterion Examination.

	RANGE	AVERAGE
Time	20 - 65 Min	40 Min
Scores	78 - 100%	91%

TROUBLESHOOTING

Opens - Shorts - Grounds - and Low Power

- Learning Objectives -

After completing this unit of instruction you will be able to:

- Define electrical troubleshooting.
- Define four fundamental steps in troubleshooting.
- Identify types of electrical troubleshooting.
- Match electrical troubles with symptoms.
- Identify test equipment used to locate electrical troubles.
- Locate troubles on schematics by test equipment readings.

NOTE: SPECIAL INSTRUCTIONS TO INSTRUCTOR

Due to the complexity of the subject matter covered in this text, you should pay particular attention to the following specific information. DO NOT just hand this package to the student.

This text may be used for initial, review, and/or remedial instruction. How and when it will be used will be determined by the student's retention of previously taught relative information and his reading ability. Students with poor retention of previously taught prerequisite knowledges should be given a demonstration or review in the use of the volt and ohmmeters.

Students with poor reading ability should be given demonstrations of troubleshooting and be allowed to perform before being given this text.

Trying to correct electrical troubles before knowing the type and location is a waste of time and effort. The efficient troubleshooter analyzes the symptoms first and then locates the trouble before any corrective action is taken.

ELECTRICAL TROUBLESHOOTING is a process of analyzing, locating, and correcting electrical troubles.

The FUNDAMENTAL STEPS of electrical troubleshooting are:

- Perform operational check.
- Determine type of trouble.
- Locate trouble.
- Perform corrective action.

Match the troubleshooting procedure with its fundamental step(s) by writing the letter(s) of the step(s) in the space(s) provided.

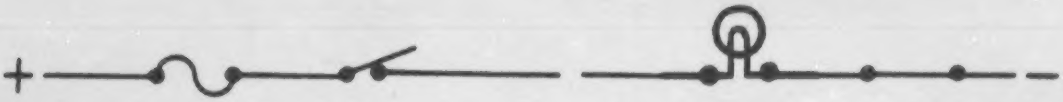
Procedures		Fundamental Steps
1. Analyze	________	a. Locate trouble
2. Locate	________	b. Perform corrective action
3. Correct	________	c. Perform operation check
		d. Determine type of trouble

Answer:
1. c, d.
2. a.
3. b.

The basic types of troubles are: Opens, Shorts, and Grounds. There's an open in the circuit when the conductor becomes broken or is unintentionally separated. Opens can also occur in the fuse, switch, or any other parts of a circuit. Naturally, if there is an open, there can be no current flow. Consequently, the units will not operate.

The symptoms of an open are, inoperative circuit and protective device not actuated. NOTE: The protective device should activate only when the circuit is shorted or overloaded.

Study the circuit below and complete the sentences.



4. The circuit shows an example of a/an ______________.

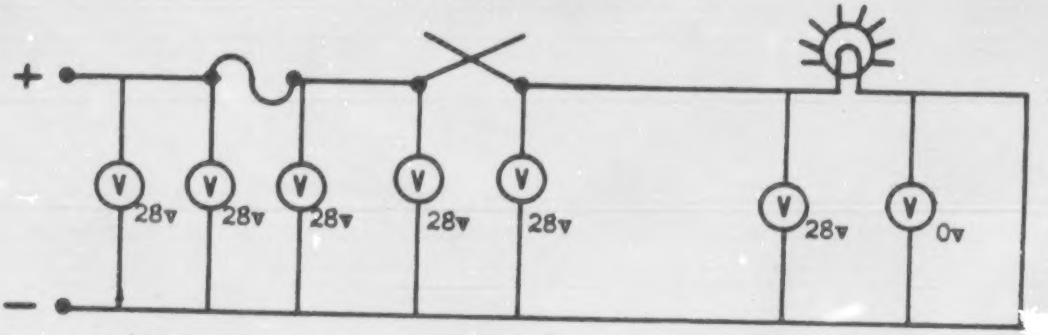
5. The other part(s) of the circuit that could cause the same type trouble is/are ______________________________.

6. The first of the four foundamental steps in troubleshooting is to ____.

Answer:	
4.	open
5.	fuse, switch, and bulb.
6.	perform operational check.

The location of an open can be found by using the voltmeter. You should, first of all, understand what a voltmeter indicates in a NORMAL operating circuit. The drawing below illustrates what a voltmeter will indicate when connected at different points in an operating circuit.

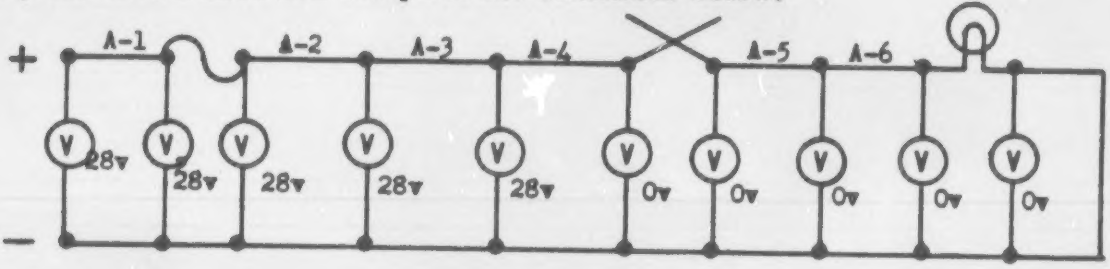
Study the illustration below and complete the sentence.



7. A voltmeter connected positive-to-negative indicates difference in voltage across the two points. A voltmeter connected negative-to-negative or positive-to-positive will indicate ________ volts.
Zero/28

The illustration below illustrates a voltmeter being used to find an open. The open is located between the last point of source voltage and the first point of zero voltage.

Study the illustration and complete the sentences below.



8. The open is located in wire A - ____.

9. With one meter lead on wire A-1 and the other on wire A-6 the meter will indicate ________ volts.
Zero/28

10. With one meter lead on wire A-1 and the other on wire A-3, the meter will indicate ________ volts.
Zero/28

11. The symtoms of an open are ________________________.

Answers: 7. Zero 8. A-4 9. 28 10. zero 11. inoperative circuit and protective device not actuated.

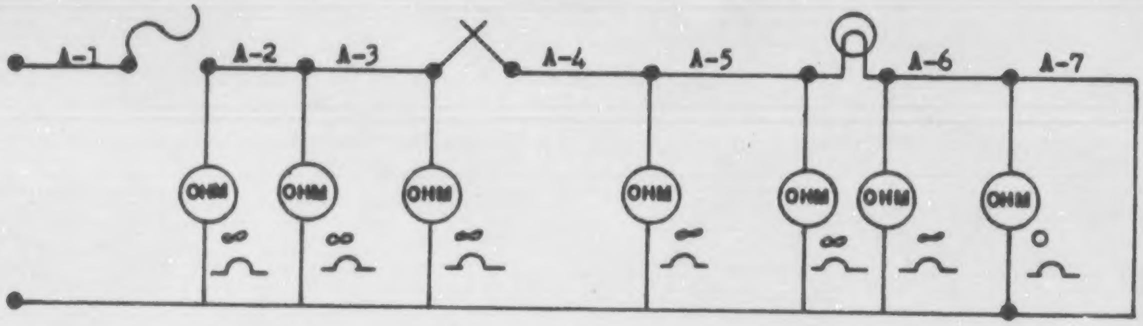
Opens can also be found by using the ohmmeter. Circuit must be disconnected from power source because the ohmmeter has its own power supply.

CAUTION: Connecting an ohmmeter to a live circuit will damage the ohmmeter.

The ohmmeter indicates continuity (uninterrupted good connection) when registering zero ohms (O) and infinity (∞ unmeasurable) when circuit is open.

When using an ohmmeter to locate an open in a circuit, the open will be located between the last infinity (∞) indication and the first zero ohm indication.

Study illustration below and complete the sentences.



12. The open is located in wire A - ________.

13. With one meter lead on wire A-2 and the other lead on wire A-5, the meter will indicate ________ (zero/infinity) ohms.

14. With one meter lead on wire A-2 and the other on wire A-7, the meter will indicate ________ (zero/infinity) ohms.

15. While using an ohmmeter the power must always be ________ (off/on).

16. While using a voltmeter the power must always be ________ (off/on).

Answer:
12. A - 6.
13. zero
14. infinity
15. off
16. on

THERE ARE THREE TYPES OF ELECTRICAL SHORTS:

Direct Short
Cross Short
Shorted Control

SYMPTOMS OF ELECTRICAL SHORTS ARE: Circuit can't be turned off, two circuits operating from only one control device, and inoperative circuit and protective device actuated.

A description of each type of short is listed below. Under each description write the proper symptom(s).

A direct short occurs in a circuit when the positive and negative wires make contact. The contact (direct short) provides a shortcut for current back to the power source which bypasses the unit of resistance. As the unit of resistance is bypassed, current flow increases causing protective device to actuate.

17. SYMPTOM -

A cross short is caused by the positive leads of two independent circuits making contact. The contact (cross short) causes units of both circuits to opera when only one switch is placed to the closed (on) position.

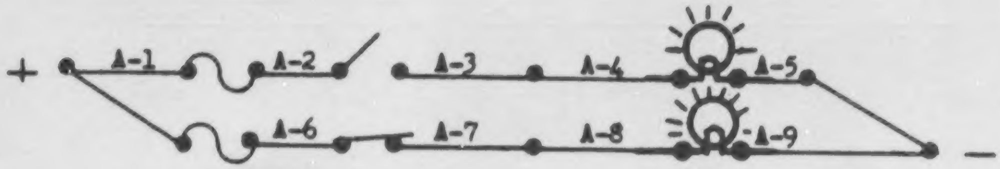
18. SYMPTOM -

A shorted control is caused by the contacts of a switch or relay being welded closed. The units will continue operating because the switch or relay will not open the circuit.

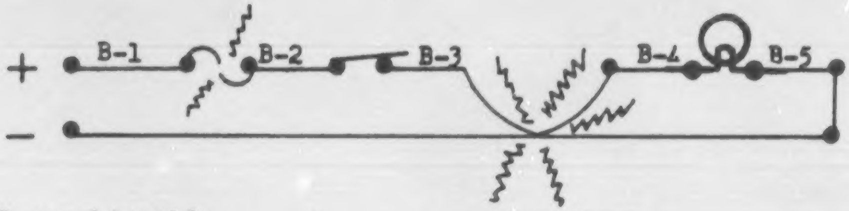
19. SYMPTOM -

Answer: 17. Inoperative circuit and protective device actuated.
18. Two circuits operating from one control device.
19. Circuit can't be turned off.

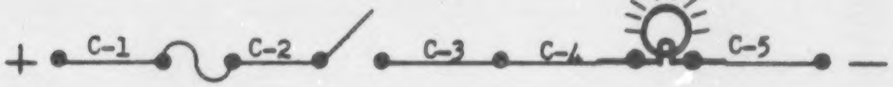
Study illustrations and write information in blanks below.


+
A-1
A-2
A-3
A-4
A-5
A-6
A-7
A-8
A-9
–

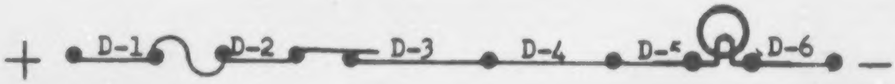
20. Type of trouble: ______________ Possible Locations: ____________


+
–
B-1
B-2
B-3
B-4
B-5

21. Type of trouble: ______________ Symptoms: ______________________


+
C-1
C-2
C-3
C-4
C-5
–

22. Type of trouble: ______________ Location: _______________________


+
D-1
D-2
D-3
D-4
D-5
D-6
–

23. Type of trouble: ______________ Symptoms: _______________________

Answer: 20. Cross short —————— (A-3 A-7) (A-4 A-8)

21. Direct short —————— inoperative circuit and protective device actuated

22. Shorted control —————— switch

23. Open —————— inoperative circuit and protective device not actuated

After you have performed an operational check (turned switch on), you determine type of trouble by the symptoms.

Match the trouble with its symptom by writing the letter a, b, c, or d, in the space by the number of the trouble.

	TROUBLES	SYMPTOMS
____	24. open	a. circuit can't be turned off.
____	25. direct short	b. inoperative circuit and protective device not actuated.
____	26. cross short	c. two circuits operating with one switch closed.
____	27. shorted control	d. inoperative circuit and protective device actuated.

NOTE: The OHMMETER is used to locate ALL types of electrical shorts.

Match the trouble with its definition.

	TROUBLES	DEFINITIONS
____	28. open	a. contacts of switch or relay will not open.
____	29. direct short	b. positive to negative contact.
____	30. cross short	c. positive to positive contact.
____	31. shorted control	d. incomplete path for current flow.

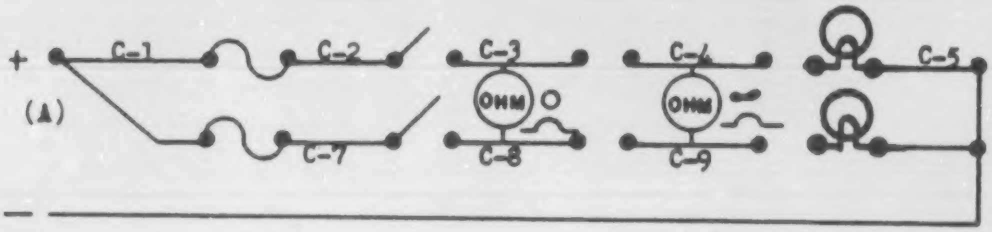
Answer:				
	24.	b.	28.	d.
	25.	d.	29.	b.
	26.	c.	30.	c.
	27.	a.	31.	a.

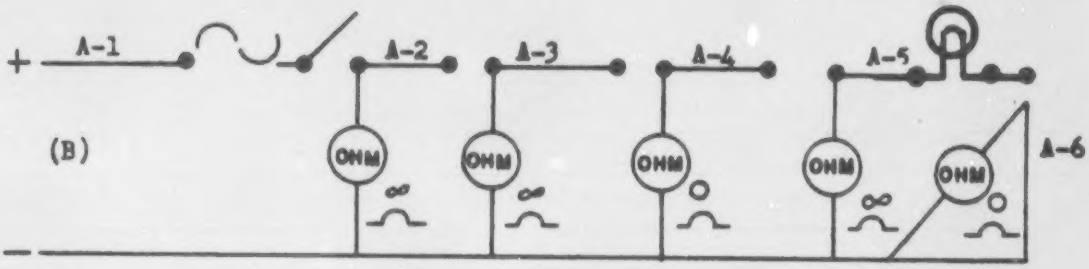
After you have performed the operational check and studied the symptoms to determine the type of trouble, the next step is to locate the trouble.

ALL TYPES OF ELECTRICAL SHORTS WILL BE LOCATED WITH THE OHMMETER

When symptoms indicate a direct short or cross short the positive leads will be isolated and the resistors (light bulbs) removed from the circuit as indicated below.

Study the drawings and complete the sentences below.





32. The short in circuit (A) is between wires C-____ and C-____.

33. The short in circuit (B) is between wire A-______ and negative wire.

34. Circuit (A) illustrates a ______________ short.

35. Circuit (B) illustrates a ______________ short.

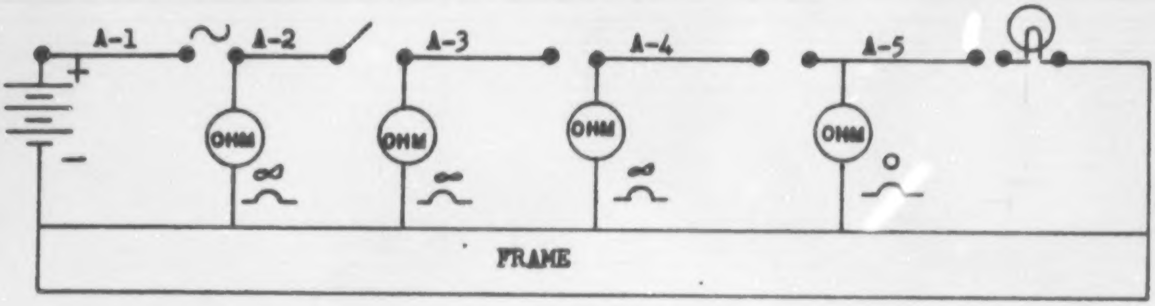
Answer:
32. C-3 and C-8
33. A-4
34. cross
35. direct

If the conductor in a one-wire circuit makes contact with the conduit, frame, or any other metallic part of the wiring system, the circuit is GROUNDED.

A ground has the same symptoms as a direct short. Power bypasses the units of resistance and goes to ground causing the protective device to actuate.

A ground can be located with an ohmmeter by isolating the one wire conductor and resistors (lamps) in a manner similar to that illustrated for a direct short.

Study the illustration and complete the sentences below.



36. The ground is located between the frame and wire A - ________.

37. The symptoms of a ground are ______________________________.

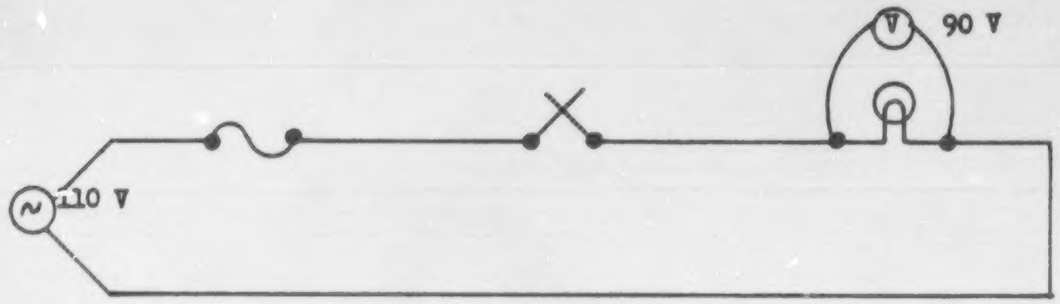
38. The ground is located where the ohmmeter reads ________________.
zero/infinity

Answer: 36. A-5
37. inoperative circuit and actuated protective device.
38. zero

Lights burning dimly, motors running sluggishly, and relays chattering are all symptoms of LOW POWER.

Low power can be caused by a loose connection, dirty switch contacts, or conductors too small for the load.

Illustrated below is one example of a low power condition.



39. Voltage drop across the unit of resistance in the illustration is _________ volts.

40. A low power condition _____________ exist.
does/does not

41. Loose connection, dirty switch contacts, and conductors too small are ___________________ of low power.
symptoms/causes

Answer: 39. 90
40. does
41. causes

REVIEW

Write in the missing word(s).

42. List the three types of electrical shorts.

____

____

____

43. All types of electrical shorts can be located with an ohmmeter. The ohmmeter reading at the location of the short will be

______________.
(Zero/Infinity)

44. When two independent circuits are energized by either of their switches, the circuits have a ____________ short.

or

Two independent circuits operating when only one switch is closed is the symptom of a ____________ short.

45. A positive and negative lead making contact and causing a protective device to actuate are the cause and symptom of a __________ short.

46. Contacts of a switch welded closed and the unit continuing to operate with the switch OFF are the cause and symptom of a ____________.

47. The positive leads of two independent circuits making contact and both circuits' units operating when one switch is closed are cause and symptom of a ________________ short.

---

42. Direct Short
    Cross Short
    Shorted Control
43. zero
44. cross
    cross
45. direct
46. shorted control
47. cross

48. Before you use the ohmmeter to locate a direct short, cross short, or ground, you must remove the resistors (light bulbs) and ____________ the positive leads.
(one word)

49. Write the name(s) of the electrical short(s) which will actuate the protective device.

50. An actuated protective device is a symptom of a ground and a ____________ short.

51. Connecting an ohmmeter to two de-energized and isolated circuits is the last steps in locating a ____________ short.

52. Units fail to operate and protective device NOT actuated when switch is placed to "CLOSED" position are the symptoms of a/an

____________.

53. The symptom of a ground is an actuated protective device. The ohmmeter reading at the location of the trouble will be

____________.
(zero/infinity)

---

48. isolate
49. direct short only
50. direct
51. cross
52. open
53. zero

CRITERION EXAMINATION

1. Which of the following statements best defines electrical troubleshooting?

   a. Determining the malfunction location.
   b. Correcting malfunctions and preventing a second occurrence.
   c. Analyzing, locating, and correcting electrical malfunctions.
   d. Prevention of electrical troubles.

2. The four fundamental steps of electrical troubleshooting are:

   a. Perform operational check, determine type of trouble, locate trouble, and perform corrective action.
   b. Select test meter, locate trouble, correct trouble, and perform operational check.
   c. De-energize circuit, perform operational check, locate trouble, and correct the trouble.
   d. Isolate circuit, select meter, locate and correct trouble.

3. An incomplete path for current flow in a circuit is defined as

   a. a direct short.
   b. a cross short.
   c. an open.
   d. a low power condition.

4. An open in an electrical circuit is indicated by which of the following symptoms?

   a. Voltmeter reads zero across the conductors.
   b. An actuated protective device.
   c. The devices operate but not efficiently.
   d. The devices fail to operate when the switch is closed.

5. To locate an open in an electric circuit with the power ON, you would

   a. use an ohmmeter.
   b. use a voltmeter.
   c. isolate the circuit into segments.
   d. wear insulating gloves.

6. To locate an open in an electric circuit with the power OFF, you would

   a. first check across the power source.
   b. break the circuit into segments.
   c. use an ohmmeter.
   d. use a voltmeter.

7. A direct short occurs when

   a. a positive lead contacts another positive lead.
   b. a negative lead contacts another negative lead.
   c. a positive lead contacts a negative lead.
   d. the contacts of a control device stick closed.

8. The symptom that indicates a direct short is

   a. a blown fuse.
   b. an increase in voltage.
   c. a decrease in current.
   d. an increase in operation.

9. To locate a direct short in a circuit, you would

   a. turn on the power and check with a voltmeter.
   b. isolate the circuit and check with an ohmmeter.
   c. replace the fuse and check for voltage drops.
   d. turn the switch on and check with an ohmmeter.

10. When checking a circuit for a direct short, the short will be located at which of the following ohmmeter readings?

    a. Between zero and infinity readings.
    b. At the zero reading.
    c. At the infinity reading.
    d. High resistance.

11. A positive to positive contact between two circuits is called

    a. a cross short.
    b. a direct short.
    c. an open short.
    d. shorted controls.

12. The symptom that indicates a cross short is

    a. an actuatuated protective device.
    b. two circuits operate from one control device.
    c. the device will not operate when switch is closed.
    d. the switch will not open the circuit.

13. To locate a cross short between two circuits, it is necessary to

    a. have both circuits energized.
    b. check both circuits for voltage drops.
    c. isolate both circuits into segments and check with ohmmeter.
    d. check each circuit separately for continuity.

14. A cross short will be located at which of the following meter readings?

    a. Zero ohmmeter reading.
    b. Infinity ohmmeter reading.
    c. Zero voltmeter reading.
    d. Voltage reading on voltmeter.

15. A cross short must occur at which of the following locations in electric circuits?

    a. Between the power source and control device.
    b. Between the control device and unit of resistance.
    c. Between the unit of resistance and ground.
    d. At the unit of resistance.

16. A shorted control is defined as

    a. a negative lead touching a positive lead.
    b. a switch having a jumper wire attached.
    c. broken contacts in a switch.
    d. contacts of a switch or relay welded together.

17. The symptom that indicates a shorted control is

    a. two devices operate from one control.
    b. an actuated protective device.
    c. the switch will not open the circuit.
    d. the switch will not close the circuit.

18. A shorted control device will be indicated by

    a. an ohmmeter reading of zero.
    b. an ohmmeter reading of infinity.
    c. a voltmeter reading applied voltage.
    d. high current reading on the ammeter.

19. If a conductor makes direct contact with the frame in a one-wire system, the result will be

    a. a cross short.
    b. a direct short.
    c. a ground.
    d. low power.

20. The symptom that indicates a ground is

    a. lights burn dim.
    b. protective device is actuated.
    c. two circuits operate from one control.
    d. circuit is inoperative, protective device not actuated.

21. When checking for a ground in a circuit the defect will be located at the

    a. zero ohmmeter reading.
    b. infinity ohmmeter reading.
    c. zero voltage reading.
    d. voltage reading on the voltmeter.

22. If a circuit device is not getting enough voltage to operate properly the trouble is called

    a. an open.
    b. a ground.
    c. reverse voltage.
    d. low power.

23. The relay in a control circuit begins to chatter when the circuit is energized. This trouble indicates a

    a. shorted circuit.
    b. low power.
    c. shorted control switch.
    d. high voltage.

24. Which of the following defects would cause a low power condition in a circuit?

    a. Contacts of control device welded together.
    b. Ammeter connected in parallel.
    c. Relay contacts stuck open.
    d. Dirty switch contacts.

2TPT-3100-04

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Technical Training

DEPARTMENT OF CIVIL ENGINEERING TRAINING

Electrical Fundamentals

June 1967

11-6

Designed For ATC Course Use

PURPOSE OF STUDY GUIDES AND WORKBOOKS

Study Guides and Workbooks are training publications authorized by Air Training Command (ATC) for student use in ATC courses.

The STUDY GUIDE (SG) presents the information you need to complete the unit of instruction, or makes assignments for you to read in other publications which contain the required information.

The WORKBOOK (WB) contains work procedures designed to help you achieve the learning objectives of the unit of instruction. Knowledge acquired from using the student study guide will help you perform the missions or exercises, solve the problems, or answer questions presented in the workbook.

THE STUDY GUIDE AND WORKBOOK (SG/WB) contains both SG and WB material under one cover. The two training publications may be combined when the WB is not designed for you to write in, or when both SG and WB are issued for you to keep.

Training publications are designed for ATC use only. They are updated as necessary for training purposes, but are NOT to be used on the job as authoritative references in preference to Technical Orders or other official publications.

VALIDATION DATA

This programmed text on Electrical Fundamentals has been validated on 85 students. Target population consisted of 22 A3C students awaiting formal training and 63 students enrolled in ABR 54330, Electrical Power Production.

The criterion test has a total of 33 responses, with 30 out of 33 being the standard of performance. Any 30 correct responses was 100%.

The following results indicate time taken to complete the program and scores obtained on the criterion test.

	Range	Average
Time	59 - 160 Minutes	112 Minutes
Scores	86% - 100%	98.2%

- Learning Objectives -

1. From a list of substances identify
   - a. Matter as being anything which occupies space and has weight.
   - b. A molecule as being the smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
   - c. An element as a substance which is made up of the same kind of atoms.
   - d. A compound as a substance which is made up of different kinds of atoms in chemical combination.
   - e. An atom as the smallest particle of an element that can take part in ordinary chemical changes.
2. From an illustration, identify electron, proton, and neutron as three components of the atom.
3. From an illustration, identify the charge of an atom as being either positive, negative, or neutral.
4. Demonstrate a knowledge of electrical current by selecting from a list of statements the one that
   - a. defines current as being the movement of free electrons through a conducting material.
   - b. identifies the unit of measure for current flow as being the ampere.
   - c. identifies the effects of current flow as being: heat, chemical change, magnetism, and shock.
5. Demonstrate a knowledge of electromotive force (EMF) by selecting from a list of statements the one that defines
   - a. Electromotive force as the electrical pressure that causes current flow.
   - b. the volt as the unit of measurement for electromotive force.

- c. chemical reaction, heat, and magnetism as the sources of electromotive force.

6. Demonstrate a knowledge of electrical resistance by selecting from a group of statements the

   - a. one that defines resistance as opposition to current flow.
   - b. one that defines ohm as the unit of measurement for resistance.
   - c. type of material, heat, length, and cross-sectional area as the factors affecting the resistance of a material.

7. Select from a list of statements one that defines an insulator as a material having extremely high resistance.

8. Select from a list of statements the one that defines a conductor as a material having low resistance.

9. From a list of materials, classify each one as an insulator or a conductor.

MATTER

Matter is made of particles in motion. This moving-particle theory explains many common facts such as evaporation of liquids, diffusion of gases, and the flow of electrical current. However, before you can use the moving-particle theory to explain current flow, or why some materials such as copper, silver, and gold make good conductors of electricity and other materials very poor conductors, you must identify the particles of matter that do the moving.

To obtain the answer to these questions is the reason you are starting the study of electricity with a basic lesson on the structure of matter.

Structure of Matter

The earth and the planets, or anything found on, around, or in them are states of matter. It exists in millions of forms, from the clouds in the sky and our food and clothes, to the soils, liquids, metals, woods, and rocks of the earth.

These many forms of matter exist in three states - liquid, solid, and gas. As you know, liquids, solids, and gases occupy space and have weight; otherwise, we could not identify these states of matter. Therefore, everything around us is an example of matter in one form or another.

Place a check (✓) by the statement that clearly defines matter.

☐ Matter is any substance that has shape and volume.

☐ Matter is anything that has weight and occupies space.

☐ Matter exists as heat, light,or sound.

☐ Matter exists as solids, because solids are the only state that has weight and volume.

Answer: ☑ Matter is anything that has weight and occupies space.

Long ago scientists discovered that the many forms of matter could be broken into smaller particles. One of the smallest particles to which matter can be broken down is the molecule.

Scientists call the smallest part of any common substance (matter) that still has the properties of the substance, a molecule. The very smallest bit of glass that can still be identified as glass is a glass molecule. The smallest bit of water that can be identified as water is a water molecule. Chemical methods can break down most molecules into still smaller particles. However, when the molecule is broken down into smaller particles, the characteristics of the original substance are destroyed.

Match the correct definition with the proper term by placing the number of the definition in the appropriate blank.

Matter ______

Molecule ______

1. Anything which occupies space and has weight.
2. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
3. Anything that can be seen and has weight.
4. Can be broken down into smaller particles and still retain its original characteristics.
5. A substance that can not be broken down into smaller particles.

Answer: Matter 1

Molecule 2

We now know that the smallest bit of water that contains all the properties of water is a molecule. But, if we were to break down this molecule of water, we would no longer have water, but instead we would have two particles of hydrogen and one particle of oxygen. When molecules are broken down in this way, no chemical method can separate them further. Chemists call these particles of matter chemical elements. Chemists also have found that every element exists as tiny particles called atoms.

If we break down an oxygen element into its smallest particle, we would find oxygen atoms only. If we break down gold in the same manner, we would find gold atoms only. An element, then, is a substance made of one kind of atom that can not be reduced to a simpler substance. Oxygen, hydrogen, copper, gold, silver, iron, sulphur, aluminum, carbon,and uranium are some of the elements known to man.

Match the correct definition with the proper term by placing the number of the definition in the appropriate blank.

Matter ______

Molecule ______

Element ______

1. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
2. A substance which is made up of the same kind of atoms.
3. A substance which is made up of one or more kinds of atoms.
4. Anything which occupies space and has weight.
5. Anything composed of two or more different atoms chemically combined.

Answer:	Matter	4
	Molecule	1
	Element	2

A substance which contains atoms of only one kind is called an element. By chemical action, we can combine elements to form completely new substances called compounds. If we break down water, we would have two atoms of hydrogen and one atom of oxygen. Water, then, is a compound formed by combining the atoms of oxygen and hydrogen. Rust is another compound. It is produced when the atoms of the iron element and the atoms of the oxygen element combine. Sugar, which is a compound, is composed of the elements of carbon, hydrogen, and oxygen. In other words, the atoms of most elements will combine with other kinds of atoms to form compounds. Salt, sugar, paper, and water are all examples of compounds formed by a combination of elements.

Match the correct definition with the proper term by placing the number of the definition in the appropriate blank.

Molecule ________

Element ________

Matter ________

Compound ________

1. Anything which occupies space and has weight.
2. A substance which is made up of different kinds of atoms in chemical combinations.
3. A substance which is made up of the same kind of atoms.
4. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
5. The smallest particle that retains its identity as a part of an element.

Answer:		
	Molecule	4
	Element	3
	Matter	1
	Compound	2

All matter is made up of particles called molecules. These molecules are composed of smaller particles linked together called atoms. If the molecule contains atoms of only one kind it is called an element. However, by chemical action, we can combine atoms of one element with the atoms of a different element to form compounds. The atom is the smallest particle of an element which can enter into chemical change. It is the combination of these atoms that give the particular molecule, element, or compound its distinctive properties.

Match the correct definition with the proper term by placing the number of the definition in the appropriate blank.

Molecule ____
Element ____
Matter ____
Compound ____
Atom ____

1. Anything which occupies space and has weight.
2. A substance which is made up of different kinds of atoms in chemical combinations.
3. A substance which is made up of the same kind of atoms.
4. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
5. The smallest particle of an element that can take part in ordinary chemical change.

Answer:	Molecule	4
	Element	3
	Matter	1
	Compound	2
	Atom	5

Now let us review the information on the Structure of Matter.

Scientists call the smallest part of any common substance that still has the properties of the substance - a molecule. Chemical methods can break down most molecules into still simpler substances, however the original substance is destroyed. Chemists call these simplest substances elements. They also have found that every element exists as tiny particles called atoms. When molecules are broken down into elements and atoms, no chemical method can separate them further. The atoms of most elements can combine with others of the same element, or of different elements, forming molecules. The molecules may then join in larger masses. Molecules and larger masses of molecules which have more than one kind of atom are called compounds. Salt, sugar, paper, and water are examples. If the large mass has only one kind of atom, it is called by the name of the element. Iron, copper, gold, and oxygen are examples.

Match the definitions with the list of terms by placing the number of the definition in the appropriate blank.

Matter ________

Molecule ________

Atom ________

Element ________

Compound ________

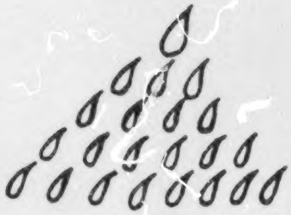
1. The smallest particle of an element that can take part in ordinary chemical change.
2. A substance which is made up of different kinds of atoms in chemical combinations.
3. A substance which is made up of the same kind of atoms.
4. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
5. Anything which occupies space and has weight.

Answer:		
	Matter	5
	Molecule	4
	Atom	1
	Element	3
	Compound	2

We have discovered that molecules are composed of very small particles known as atoms. An atom is the smallest particle that retains its identity as a part of the element from which it is divided. A further division of the atom would yield particles that bear no relationship to the original element from which they came. Now let us break down some matter and identify the atom.

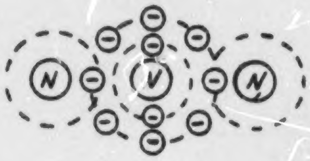
Observe the sketch below, and identify which particles represent the atom by writing the word ATOM in the appropriate blank.

Matter



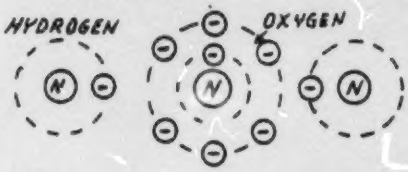
______

Compound



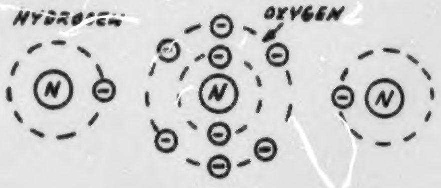
______

Elements



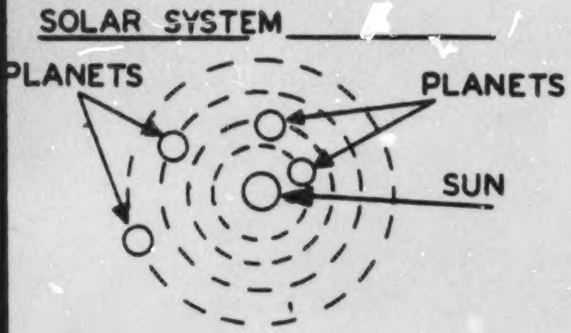
______ ______ ______

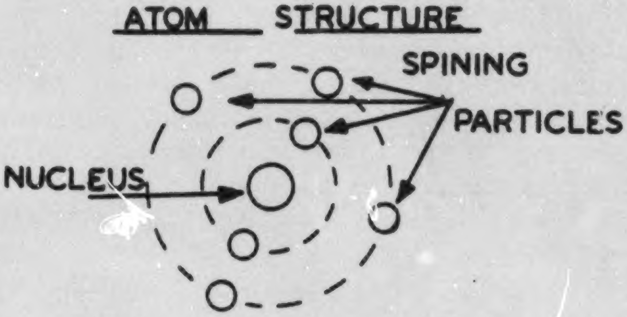
Answer:



Atom Atom Atom

ll atoms are composed of ~~tiny~~ particles. The centermost part is known as he nucleus. The nucleus of an atom may be compared to the sun in our solar ystem around which planets revolve. The nucleus accounts for almost all he weight (mass) of the atom, and furnishes the force that causes other particles f the atom to spin around the nucleus in the same manner as the planets move n orbits around the sun. In the sketch below, notice the resemblance of an tom to our solar system.





Place a (✓) by each true statement.

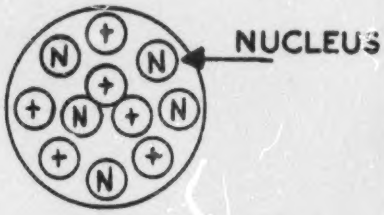
- ☐ There are at least two different particles contained in an atom.
- ☐ The structure of the solar system and the atom are identical.
- ☐ The nucleus is the force that holds the atom together.
- ☐ The planets and outer particles are both in continuous motion.

---

nswer:

- ☑ There are at least two different particles contained in an atom.
- ☑ The nucleus is the force that holds the atom together.
- ☑ The planets and outer particles are both in continuous motion.

The nucleus contains two of the three parts of the atom. These two parts are known as the proton and the neutron. The proton will always have a positive charge and every atom must have at least one proton in its nucleus. The symbol used to represent the proton is ⊕ . The neutron is a sub atomic particle found in the nucleus of the atom. Although it has a diameter and mass approximately equal to the proton, it has no electrical charge. Hence, it can be thought of as one proton and one electron. The neutron is required to stabilize the atomic structure of the more complex type atoms. Its symbol is Ⓝ . The protons and the neutrons are packed closely together to form the nucleus of the atom. Since the neutron has no electrical charge and the proton has a positive charge, the nucleus of an atom will always have a positive (+) charge and is the particle that maintains the stability of the atom.



In this nucleus, how many protons and neutrons are there?

( ) Neutrons

( ) Protons

Place a (✓) by each true statement.

☐ The neutron does not affect the stability of the nucleus.

☐ The nucleus will always have a positive charge.

☐ The nucleus maintains the stability of the atom.

☐ The neutron is responsible for the positive charge of the nucleus.

☐ The atom will always have a positive charge.

Answer: (5) Neutrons

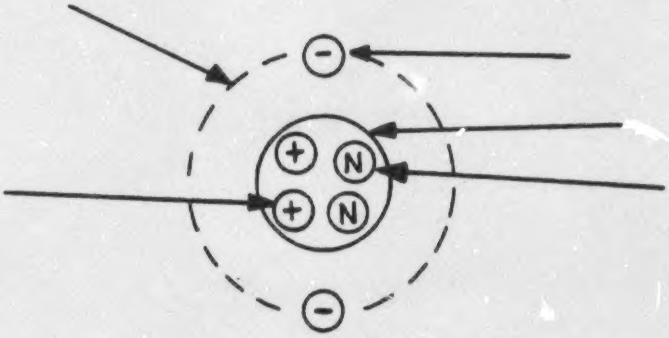
(6) Protons

☑ The nucleus will always have a positive charge.

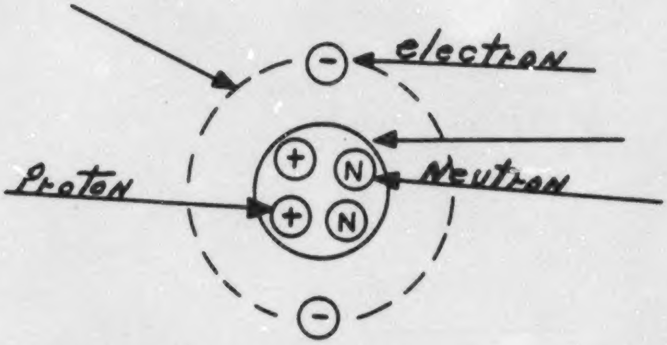
☑ The nucleus maintains the stability of the atom.

The third part of the atom is the electron. Electrons are the particles that circle about the nucleus of an atom in paths called shells. There can be as many as seven (7) shells around the nucleus of an atom. Each shell will have a number of electrons orbiting in it. The number of electrons that each shell can hold depends upon the distance of the shell from the nucleus. However, the total number of electrons orbiting in the shells will be the same as the number of protons in the nucleus. The electron has a negative charge and the symbol is ⊖ . It is this negative charge that helps hold the electrons in orbit around the nucleus.

In the sketch of an atom shown below, identify the three parts of the atom by writing the word Electron, Proton, and Neutron in the appropriate blank.



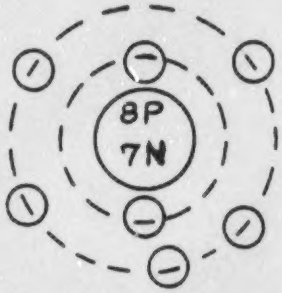
Answer:



Now let us review the information on the structure of an atom.

Observe the sketch of the atom shown below, and answer the following questions.

The "8 P" and the "7 N" represent the number of protons and neutrons in the nucleus.



1. How many shells are there in this atom? __________.

2. Does the number of protons in the nucleus equal the number of orbiting electrons? __________.

3. Does the 7 neutrons have any effect on the electrical charge of the protons or the electrons? __________.

4. Can the protons and neutrons be separated? __________.

5. What particle of the atom rotates around the neucleus? __________.

6. What particle accounts for almost all the weight of the atom? __________.

7. Draw the symbol for a proton. __________.

8. Draw the symbol for a neutron. __________.

9. What two particles of the atom form the nucleus? __________.

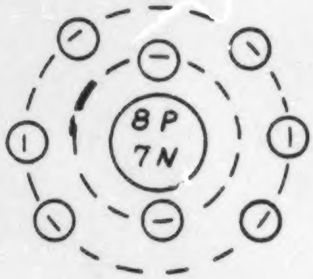
10. What does the neutron add to the atom? __________.

Answer: 1. 2; 2. No; 3. No; 4. No; 5. Electron; 6. Nucleus; 7. ⊕ ; 8. Ⓝ ; 9. Proton & Neutron; 10. Weight or Mass.

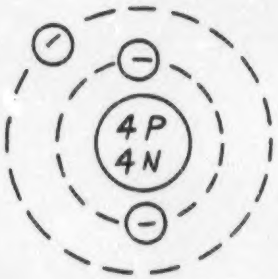
One of the fundamental laws of electricity is that like charges repel each other, and unlike charges attract each other. This law explains the bond that exists in the atom between the positively (+) charged protons of the nucleus and the negatively (−) charged electrons orbiting around the nucleus. Since the two particles (electrons and protons) have unlike charges, they will be drawn toward each other until the positive charge exactly balances the negative charge. This balanced or neutral condition holds the electrons in the various orbits around the nucleus. Under normal conditions the number of electrons in the orbital shells of an atom will be the same as the number of protons in the nucleus. Therefore, if the sum of the positive charges exactly equals the sum of the negative charges, the atom will be neutral.

Place a check (√) by the atoms that are electrically neutral.

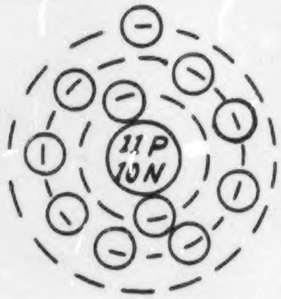
A ______



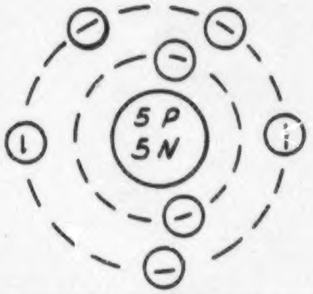
B ______



C ______



D ______

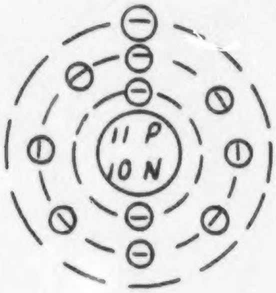


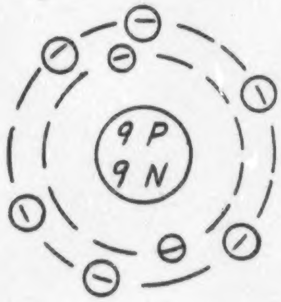
Answer: A √

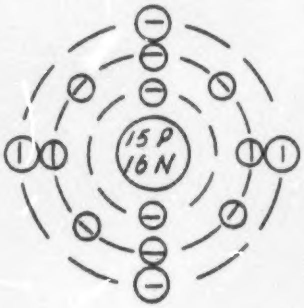
C √

In the normal atom the sum of the positive charges of the protons in the nucleus exactly equals the sum of the negative charges of the electrons - such an atom is neutral. If for some reason a few electrons are torn away from the neutral atom, the atom becomes charged and is called a positive ion. Therefore, atoms having a positive charge are the result of an atom losing one or more of the orbiting electrons. In other words, a positively charged atom will have more protons in its nucleus than there are orbiting electrons.

Identify the electrical condition of each illustrated atom by writing the word Positive or Neutral in the appropriate blank.







A____________________ B____________________ C____________________

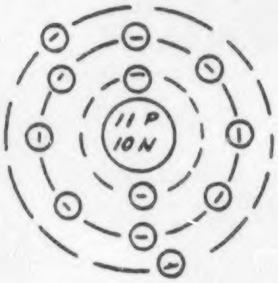
Answer: A. Neutral

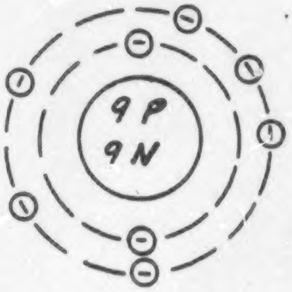
B. Positive

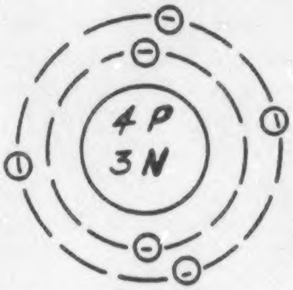
C. Positive

If the electrons that are torn away from the neutral atom (as explained in the previous paragraph) gather on some other neutral atom, that atom becomes negatively charged, and is called a negative ion. If an electron moved to an already neutral atom, the atom would then have an excess of electrons. The result would be the atom having a negative charge.

Identify the electrical charge of each illustrated atom by writing the word Positive or Negative in the appropriate blank.





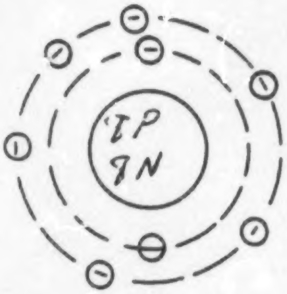


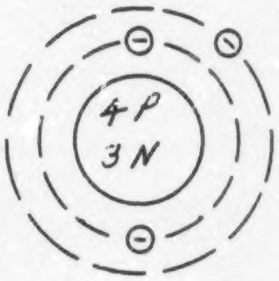
A_______________ B_______________ C_______________

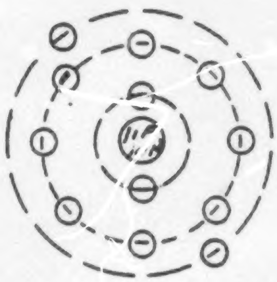
Answer:
A. Negative
B. Positive
C. Negative

Now let us review the information on the electrical charges an atom may contain. We know that an atom may have a number of shells with a number of electrons orbiting in each shell, and normally there is one orbiting electron for each proton in the nucleus. The sum of the positive charges of the protons exactly equals the sum of the negative charges of the electrons. In other words, under normal conditions atoms are neutral; all atoms strive to remain electrically neutral. However, if for some reason a few electrons are torn away from a neutral atom, it has an excess of protons and is now a positively charged atom. If the electrons that are torn away from the neutral atom gather on some other neutral atom, it now has an excess of electrons and is a negatively charged atom.

Identify the electrical charge of each illustrated atom by writing the word Positive, Negative, or Neutral in the appropriate blank.







A______________ B______________ C______________

Answer: A. Neutral

B. Positive

C. Negative

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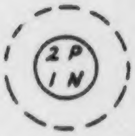
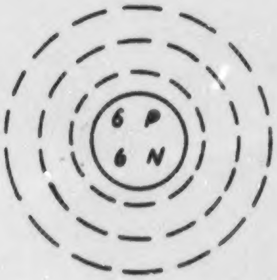
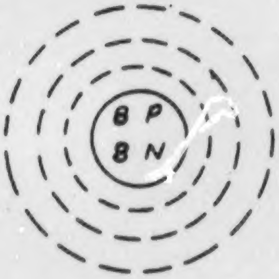
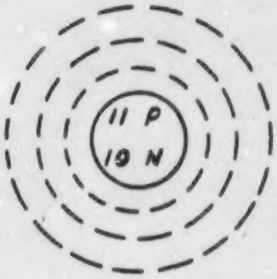
We observed that some electrons are close to the nucleus and others are farther away. The number of shells and the number of electrons in each shell depends upon the complexity of the atom. The shell closest to the nucleus can hold only two electrons. The next orbital shell can hold from one to eight electrons. The first shell must be filled with two electrons before any electrons can move into the second shell. Likewise, the second shell must be filled with its eight electrons before any electrons appear in the third shell. Therefore, if there are more than 10 electrons in the atom, an additional orbital shell farther away from the nucleus is required.

Observe the sketches below, and draw in the correct number of electrons that each shell should contain. Remember, there are the same number of electrons in orbit as there are protons in the nucleus.









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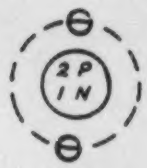
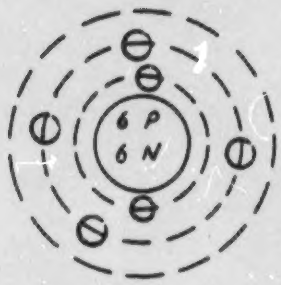
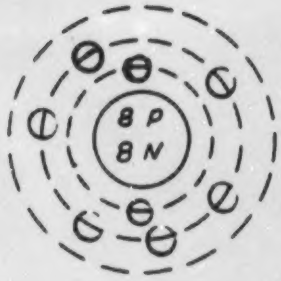
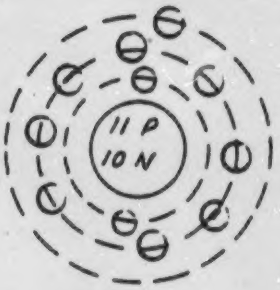

2 P
1 N


6 P
6 N

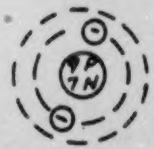

8 P
8 N


11 P
10 N

It is now apparent that the first shell can hold up to two electrons and the second shell can hold up to eight electrons. Also, each shell (first and second) must be filled completely before the third shell is formed. (See Table, Page 18A). The requirement to fill the shell completely before the next shell is formed applies only to the first and second shells. Continuing outward from the nucleus, the third shell can hold up to 18 electrons, the fourth shell up to 32 electrons. etc. However, the outer shell can hold only up to eight electrons. The next to the outer shell can hold only up to 18 electrons. When the outer shell is filled (8 electrons), and the next to the outer shell is filled (18 electrons), a new shell will be formed when another electron is added to the atom.

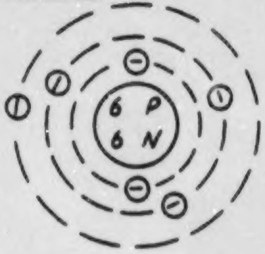
Refer to the Table on Electron Structure of Atoms on Page 18A. This Table will help you accomplish the following activities. Answer the following questions:

1. If there are eight electrons in the seventh (7th) shell of an atom, how many electrons would the 6th shell hold?
2. What is the maximum number of electrons that can be contained in the first shell of any atom?
3. What is the maximum number of electrons that can be contained in the second shell, third shell and the fourth shell?
4. Would this atom need a third shell?

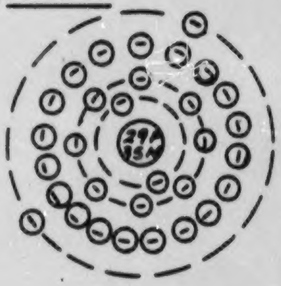


5. Which of the atoms sketched below contains the correct number of shells around the nucleus and the correct number of electrons in each shell? Place a (✓) by the correctly drawn atoms.

A______

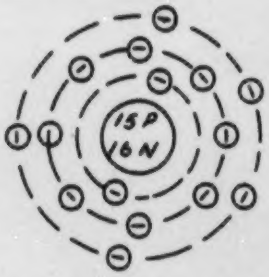


B______

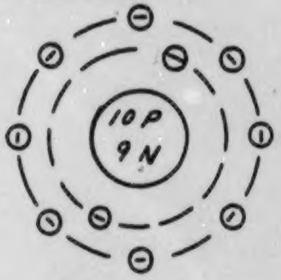


Answers:
1. 18
2. 2
3. 8, 18, 32
4. No
5. C. D.

C______



D______



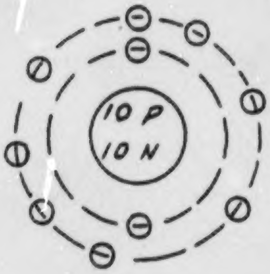
ELECTRON STRUCTURE OF ATOMS*

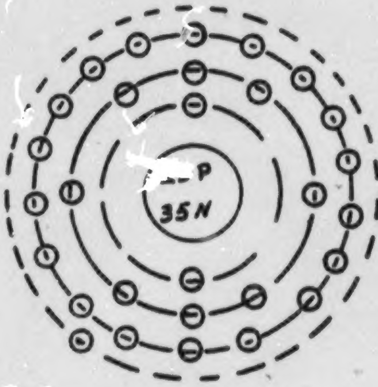
ATOMIC NUMBER	ATOM	SHELL					ATOMIC NUMBER	ATOM	SHELL						
		1	2	3	4	5			1	2	3	4	5	6	7
1	Hydrogen H	1					50	Tin Sn	2	8	18	18	4	0	0
2	Helium He	2					51	Antimony Sb	2	8	18	18	5		
3	Lithium Li	2	1				52	Tellurium Te	2	8	18	18	6		
4	Beryllium Be	2	2				53	Iodine I	2	8	18	18	7		
5	Boron B	2	3				54	Xenon Xe	2	8	18	18	8		
6	Carbon C	2	4				55	Cesium Cs	2	8	18	18	8	1	
7	Nitrogen N	2	5				56	Barium Ba	2	8	18	18	8	2	
8	Oxygen O	2	6				57	Lanthunum La	2	8	18	18	9	2	
9	Fluorine F	2	7				58	Cerium Ce	2	8	18	19	9	2	
10	Neon Ne	2	8				59	Praseodymium Pr	2	8	18	20	9	2	
11	Sodium Na	2	8	1			60	Neodymium Nd	2	8	18	21	9	2	
12	Magnesium Mg	2	8	2			61	Promethium Pm	2	8	18	22	9	2	
13	Aluminum Al	2	8	3			62	Samarium Sm	2	8	18	23	9	2	
14	Silicon Si	2	8	4			63	Europium Eu	2	8	18	24	9	2	
15	Phosphorous P	2	8	5			64	Gadolinium Gd	2	8	18	25	9	2	
16	Sulphur S	2	8	6			65	Terbium Tb	2	8	18	26	9	2	
17	Chlorine Cl	2	8	7			66	Dysprosium Dy	2	8	18	27	9	2	
18	Argon A	2	8	8			67	Holmium Ho	2	8	18	28	9	2	
19	Potassium K	2	8	8	1		68	Erbium Er	2	8	18	29	9	2	
20	Calcium Ca	2	8	8	2		69	Thulium Tm	2	8	18	30	9	2	
21	Scandium Sc	2	8	9	2		70	Ytterbium Yb	2	8	18	31	9	2	
22	Titanium Ti	2	8	10	2		71	Lutetium Lu	2	8	18	32	9	2	
23	Vanadium V	2	8	11	2		72	Hafnium Hf	2	8	18	32	10	2	
24	Chromium Cr	2	8	13	1		73	Tantalum Ta	2	8	18	32	11	2	
25	Manganese Mn	2	8	13	2		74	Tungsten W	2	8	18	32	12	2	
26	Iron Fe	2	8	14	2		75	Rhenium Re	2	8	18	32	13	2	
27	Cobalt Co	2	8	15	2		76	Osmium Os	2	8	18	32	14	2	
28	Nickel Ni	2	8	16	2		77	Iridium Ir	2	8	18	32	15	2	
29	Copper Cu	2	8	18	1		78	Platinum Pt	2	8	18	32	16	2	
30	Zinc Zn	2	8	18	2		79	Gold Au	2	8	18	32	18	1	
31	Gallium Ga	2	8	18	3		80	Mercury Hg	2	8	18	32	18	2	
32	Germanium Ge	2	8	18	4		81	Thallium Tl	2	8	18	32	18	3	
33	Arsenic As	2	8	18	5		82	Lead Pb	2	8	18	32	18	4	
34	Selenium Se	2	8	18	6		83	Bismuth Bi	2	8	18	32	18	5	
35	Bromine Br	2	8	18	7		84	Polonium Po	2	8	18	32	18	6	
36	Krypton Kr	2	8	18	8		85	Astitine At	2	8	18	32	18	7	
37	Rubidium Rb	2	8	18	8	1	86	Radon Rn	2	8	18	32	18	8	
38	Strontium Sr	2	8	18	8	2	87	Francium Fr	2	8	18	32	18	8	1
39	Yttrium Y	2	8	18	9	2	88	Radium Ra	2	8	18	32	18	8	2
40	Zirconium Zr	2	8	18	10	2	89	Actinium Ac	2	8	18	32	18	9	2
41	Niobium Nb	2	8	18	12	1	90	Thorium Th	2	8	18	32	19	9	2
42	Molybdenum Mo	2	8	18	13	1	91	Protactinium Pa	2	8	18	32	20	9	2
43	Techetium Te	2	8	18	14	1	92	Uranium U	2	8	18	32	21	9	2
44	Ruthenium Ru	2	8	18	15	1	93	Neptunium Np	2	8	18	32	22	9	2
45	Rhodium Rh	2	8	18	16	1	94	Plutonium Pu	2	8	18	32	23	9	2
46	Palladium Pd	2	8	18	18	0	95	Americium Am	2	8	18	32	24	9	2
17	Silver Ag	2	8	18	18	1	96	Curium Cm	2	8	18	32	25	9	2
48	Cadmium Cd	2	8	18	18	2	97	Berkelium Bk	2	8	18	32	26	9	2
49	Indium In	2	8	18	18	3	98	Californium Cf	2	8	18	32	27	9	2

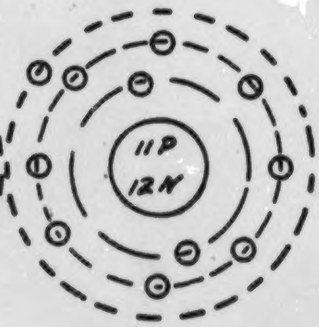
*This table is used solely as an example and is not complete. There are actually 106 known elements.

It is possible to determine whether a given substance will easily release electrons by noting the distance the shell is from the nucleus and the number of electrons in each shell. The first shell (the shell next to the nucleus) is complete and chemically stable when it has two electrons. The electrons, in this case, are bound tightly around the nucleus, and a great force is required to dislodge the electrons. The second shell must have eight electrons before it is complete or chemically stable. If the shell in question is complete, a superior force would also be required to remove the electrons. Now, if there are only two electrons in this second shell, it would surrender the electrons with relative ease. The unstable condition and distance the shell is from the nucleus permit the electrons to be easily dislodged from the atom.

Place a (✓) by the atoms which would more easily release their electrons.





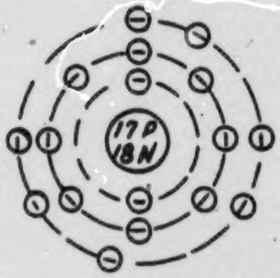


A_______________ B_______________ C_______________

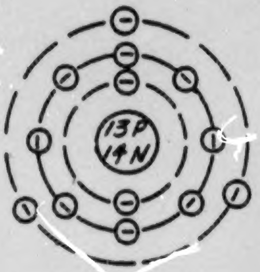
Answer: b. ✓
c. ✓

In other words, when the outermost shell of an atom has eight (8) electrons, the shell is stable and it will refuse to give up or take on additional electrons. We know that the other shells closer to the nucleus are also stable and will not give up electrons. Therefore, it is this outermost shell that determines if electrons can be drawn away from the atom by a small outside force. The outermost shell is called the valence shell and the electrons in this shell are called valence electrons. When the valence shell of an atom is more than half full (5 or more electrons) the atom tends to take on electrons to complete its shell and will refuse to give them up. If the valence shell is less than half full (3 or less) the atom tends to give up electrons. The less valence electrons there are in the valence shell, the easier it is to free them.

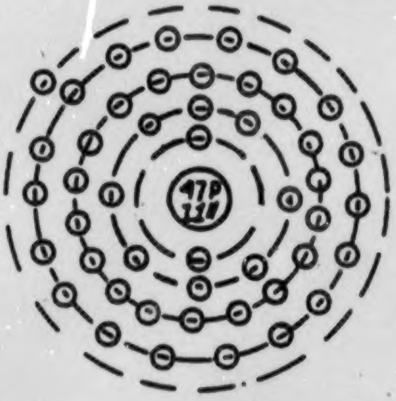
Place a check (✓) by the atoms that readily give up their valence electrons.



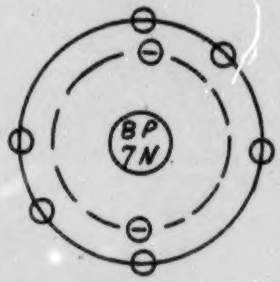
A ____________



B ____________



C ____________



D ____________

Answer: B. ✓

C. ✓

Once an orbital electron is removed from an atom, it is called a free electron. The valence electrons of certain metals are so loosely bound to the nucleus that a small outside force can move the electron from the atom. The small amount of energy created by room temperature can cause an electron to be moved from the atom and become a free electron. This free electron may move in any direction through the metal in search of a positively charged atom. In other words, there is a random movement of electrons among the atoms within the metal.

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When electrons are dislodged from their orbit and permitted to drift outside the bounds of the atom, these electrons are known as

a. valence electrons.

b. free electrons.

c. random electrons.

d. ionized electrons.

(check correct answer)

Answer: b. Free electrons

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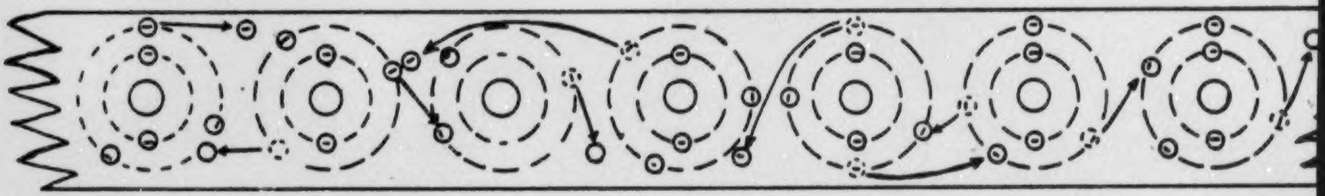
It is apparent that the free electrons moving about the interior of the metal may again recombine with atoms. There is still an interchange of free electrons between atoms, but there is no general trend in either one direction or the other. The electrons do not actually flow from one end of the material to the other, unless they are forced to do so by the application of some external force. They are not considered as flowing in the sense that an electric current flows. In other words, to have a current flow, there must be a constant pressure to maintain a steady drift of electrons and a suitable path through which the electrons may flow.

Study the movement of the free electrons in the illustration of the copper wire.



Answer the following questions.

1. Will there be a current flow in this copper wire? ______ (Yes) ______ (No)

2. Is there an interchange of free electrons between atoms? ______ (Yes) ______ (No)

3. Once the electrons are dislodged from the atom, do they remain as free electrons or do they recombine with other atoms?

   ____________________________________.

4. Name two requirements necessary to maintain a current flow.

   a. ______________________ b. ______________________.

Answers: 1. No; 2. Yes; 3. Recombine with other atoms;
4. a. Constant pressure. b. A suitable path to move throug

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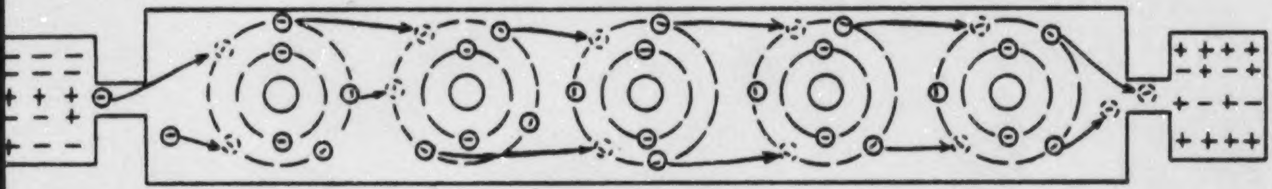
If a positively charged body (having too few electrons) and a negatively charged body (having an excess of electrons) are placed at opposite ends of the copper wire, the free electrons in the copper wire will be attached to the positively charged body. The force caused by the two differently charged bodies cause all of the free electrons to move in the same direction through the wire. The random movement of electrons no longer prevails. The movement of these free electrons through the conducting copper wire toward the positively charged body constitutes an electric current.

Study the illustration below.



Answer the following questions.

1. Does the movement of free electrons in the wire indicate a current flow?

   ____ (Yes) ____ (No)

2. The electrons in the wire move toward the positive charge.

   ____ (Yes) ____ (No)

3. What force causes the electrons to drift through the wire?

   ________________________________.

4. What is the name of the electron in the outermost shell?

   ____________________.

Answer: 1. Yes; 2. Yes; 3. Differently charged bodies;
4. Valence electrons

When a battery is applied to the wire, an excess of electrons is applied to one end of the wire and a deficiency of electrons at the other end. The free electrons are caused to flow or drift toward the end with a deficiency of electrons. This is the same condition explained in the previous paragraph - two unlike charges. In the general drift of electrons along a wire carrying an electric current, each electron travels only a short distance before colliding with and becoming attached to an atom. However, this collision knocks off one or more electrons from the atom which become free electrons. In this manner the general drift continues throughout the entire length of the wire. This drift of electrons through the wire is referred to as a "FLOW OF CURRENT."

Check (✓) the correct answer below.

The definition of electrical current is the

a. flow of electrical force through a conducting material.

b. movement of free electrons through a conducting material.

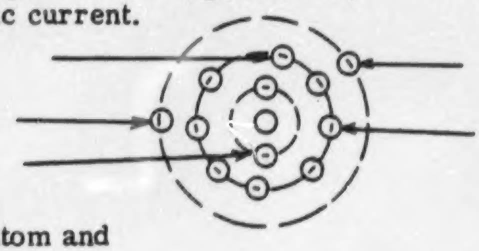
c. flow of magnetic flux around a conducting material.

d. result of ohms through a resistive material.

Answer: b.

Now let us review the information on the theory of current flow. The tendency of an atom to give up its electrons depends upon a characteristic called "Chemical Stability." An atom is said to be stable if its valence shell is full; that is, when the valence shell contains eight valence electrons. A great amount of force is required to dislodge the electrons of a chemically stable atom. When the valence shell of an atom is more than half full, the atom tends to take on electrons. When an atom's valence shell is less than half full, the atom will give up electrons. When a small amount of force is added to a valence electron, it will move out of the valence shell and become a free electron. If the movement of electrons is controlled so that the free electrons move in the same direction at the same time through a conducting material, we have a flow of electrons which is called electric current.

Check (✓) the correct answer.



1. Identify the valence electrons of the atom. (Place a check in the appropriate blank)
2. When electrons are dislodged from an atom and allowed to move in any direction through the material, these electrons are known as

   a. electrical current.

   b. random electrons.

   c. free electrons.

   d. free ions.

3. The definition of electrical current is the

   a. movement of electrical force through a conducting material.

   b. flow of magnetic flux around a conducting material.

   c. movement of free electrons through a conducting material.

   d. flow of chemically stable atoms through a conducting material.

Check the back of this page for correct answer.

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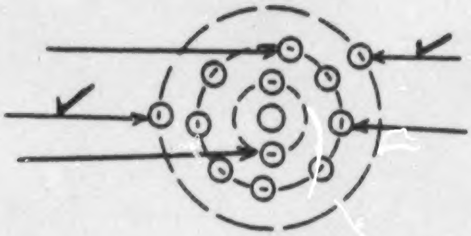
Answer: 1. 2. C; 3. C.



Now that we know free electrons in the form of electrical current can be moved from point to point in a conducting material, the unit of measurement for electrical current can be presented. The negative charge of an electron is called an elemental charge, and it is the smallest electrical charge which has been discovered. The positive charge of a proton is also called an elemental charge. These charges are equal and opposite in electrical strength. Since the mobile member of the atom is the electron, it moves this charge through the conducting material. The rate at which the electrons move this charge through the material determines the amount of current flow.

When we measure electrical current, we determine the

a. strength of each electrical charge.

b. flow rate of the current.

c. charge that is carried by the electron.

d. charge remaining on the proton.

Answer: b.

The number of elemental charges that pass any point in a conducting material each second is the rate of flow of electrical current. However, the elemental charge is too small for practical use. This charge is so small that it would require several sheets of paper to record the amount of current used in your home in one day. We must have a number of elemental charges measured as a unit of current. This unit is called a coulomb. It takes 6,250 million billion elemental charges to make one coulomb. The coulomb is the unit quantity, or unit charge that is computed when determining the flow rate of current.

When we measure current, the unit charge used to determine the flow rate per second is the

a. coulomb.

b. elemental charge.

c. electron.

d. proton.

Answer: a.

The rate at which a current of water flows through a pipe is expressed as a certain number of gallons or cubic feet per second. In the same way, a current of electricity may be expressed as a certain quantity of charge flowing per second past a certain point in the conducting material. As you know, we use the coulomb as the quantity of charge that goes by per second. The rate at which the unit charge flow is measured is amperes. If one coulomb passes a point each second, the current flow would be one ampere. Therefore, ampere is the number of coulombs passing a point per second in a conducting material. The unit of measure used to express the rate at which current flows is the ampere.

The unit of measure for current flow is the

a. elemental charge.

b. proton.

c. ampere.

d. electron.

Answer: c.

Now that we know that current is the movement of electrons through a conducting material, and the total amount of charge transferred by the moving electrons is measured in amperes, let us discuss the force that causes the movement of the electrons. You should remember that when a wire is connected between a point with an excessive number of electrons and another point with a deficiency of electrons, there will be a movement of the free electrons. This movement is explained by the fact that an electrical pressure exists whenever there are more electrons at one point than at the other. The greater the difference in the number of electrons, the greater the electrical pressure and the greater the amount of electron flow. This electrical pressure between the two points is known as a difference of potential.

The movement of electrons through a conducting material is the result of

a. the elemental charges.

b. a difference of potential.

c. two positively charged atoms.

d. two negatively charged atoms.

Answer: b.

When two bodies have unequal charges, a difference of potential exists between them. This difference of potential causes a current to flow. However, the drift of the electrons will tend to neutralize the unequal charge of the two bodies and no difference of potential will exist. Therefore, we must have a force that will maintain the difference of potential between the two bodies. In other words, we must have a force that will remove electrons from one point and pile up electrons on the other. This force is known as electromotive force. Now, if a device that causes a continuous electromotive force is connected between two points, a difference of potential is maintained and a continuous current will flow.

The electrical force that causes current flow through a conducting material is called

a. electromotive force.

b. electron flow.

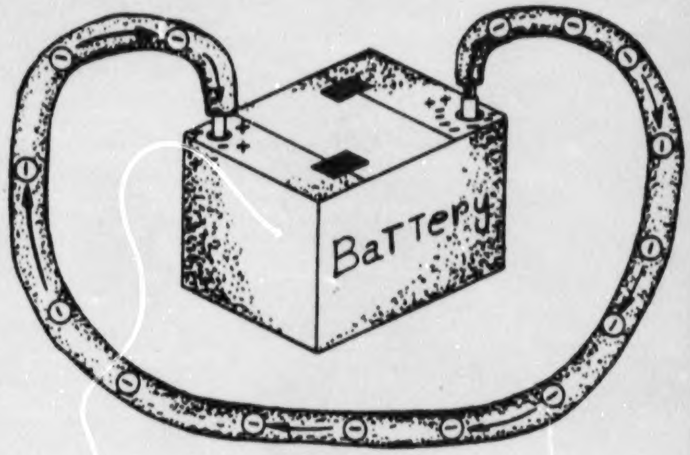
c. unequal charges.

d. coulombs.

Answer: a.

In order to maintain a steady flow of current, we must have a continuous electromotive force. That is, one end of the wire must have an excess of electrons and the other end a deficiency of electrons.

Note in the illustration to the right that the electrons flow away from one post of the battery and toward the other post. The reason for this is that a battery creates an excess of electrons at one post and it has a deficiency of electrons at the other post. The battery then is a constant source of electromotive force.



The pressure or force that causes current to flow is called

a. the elemental charge.

b. electromotive force.

c. electron flow.

d. a deficiency of electrons.

Answer: b.

This electromotive force, or pressure, is usually abbreviated "E. M. F." This EMF is expressed in units called Volts. The volt is a unit of electromotive force and is measured with a device called a voltmeter. When the EMF of a battery is mentioned, it is referred to as having a certain number of volts. The same is true of the wall plug in your house. When we measure the EMF of the plug, we say that there are 110 volts available.

The electrical pressure that causes current flow through a conducting material is called

a. an elemental charge.

b. a deficiency of electrons.

c. electromotive force.

d. electron flow.

(Check the correct answer)

The unit of measurement for electromotive force is the

a. ampere.

b. watt.

c. ohm.

d. volt.

(Check the correct answer)

Answer: c; d.

To summarize: When two bodies have unequal charges, a difference of potential exists between them. This potential difference causes a current to flow. The two bodies are maintained at a continuous difference of potential because of a constant source of electromotive force which creates an excess of electrons at one point and a deficiency of electrons at the other point. This electromotive force driving the current is measured in volts. One volt, when steadily applied to a conducting material that has one unit of resistance, will produce a current of one ampere.

- Check the correct answer -

The electrical pressure that causes current to flow through a conducting material is called

a. electromotive force.

b. electron flow.

c. a deficiency of electrons.

d. electron force.

The unit of measurement for electromotive force is the

a. ampere.

b. resistance.

c. volt.

d. ohm.

Answer: a.; c.

In order to cause electrons to move in the same direction through a conducting material, an electromotive force must be available. Several methods can be used to supply the electromotive force. The voltaic cell is one way in which an electromotive force can be produced. The cell consists of two metals, such as zinc and copper, placed in a solution of acid and water. The resulting chemical reaction produces an electromotive force between the two metals. The zinc takes on a negative charge and the copper metal takes on a positive charge. The metals thus become positively and negatively charged respectively and in this case an electromotive force of about 1.5 volts is produced. The same action takes place in the common flashlight battery or automobile battery.

One method used to supply electromotive force is by

a. chemical reaction

b. two like charges

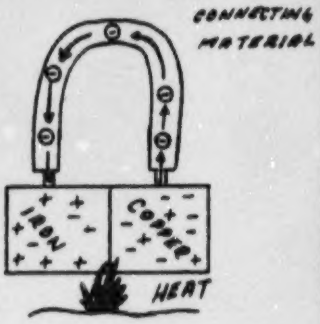
c. two unlike metals

d. a solution of acid and water

(Check the correct answer)

Answer: a.

Another method used to produce EMF is by heat. For example, a thermocouple is a device which converts heat directly into electromotive force. The thermocouple consists of two dissimilar metals in contact. The metals can be copper and iron or any other dissimilar metals. When a conducting material connects the dissimilar metals and the point of contact of the two is heated, an EMF is developed which causes current to flow in the connecting wire. Note that the copper gives up its free electrons which flow through the connecting wire to the iron. This gives us a negative and positively charged body which causes current flow.



Two methods used to supply electromotive force is by

a. heat and chemical reaction.

b. heat and two like charges.

c. two unlike metals and heat.

d. two unlike metals and a solution of acid.

Answer: a.

The third method used to produce EMF is by magnetism. When a current flows through a conducting material a magnetic field is set up around the material. If we take a copper wire and form it into a coil, the magnetic field will be very strong. Now if we take another copper wire and move it through the magnetic field we will produce an electromotive force in the moving wire. In order to produce EMF by magnetism, we must have three necessary factors: a magnetic field, a conducting material, and relative motion. 4/2

The three sources of electromotive force are

a. current, voltage, and resistance.

b. magnetism, heat, and chemical reaction.

c. voltage, heat, and mechanical reaction.

d. chemical reaction, relative motion, and magnetic field.

Answer: b.

Now let us review. Current is the movement of free electrons through a conducting material. The unit charge transferred by moving electrons is expressed in coulombs. The rate at which the unit charge flow is measured in amperes. The external force or electrical pressure that cause a continuous current flow is known as electromotive force, and the unit of measurement for it is the volt. There are three methods of producing this EMF. One method utilizes chemical action between two different metals in a solution of acid and water. Another method utilizes two different metals and heat. The third method involves rotating conductors (wire) through a magnetic field. Each method creates more electrons at one point than at the other - thus current flow.

(Check the correct answers)

1. The definition of electrical current is the

   a. flow of electrical force through a conducting material.
   b. movement of free electrons through a conducting material.
   c. flow of magnetic force through a conducting material.
   d. result of resistance through a conducting material.

2. The unit of measure for current flow is the

   a. elemental charge.
   b. coulomb.
   c. ampere.
   d. electron.

3. The pressure or force that causes current to flow is called

   a. the elemental charge.
   b. electron flow.
   c. electromotive force.
   d. a deficiency of electrons.

4. The unit of measurement for electromotive force is the

   a. ampere.
   b. resistance.
   c. volt.
   d. ohm.

5. The three sources of electromotive force are

   a. current, voltage, and resistance.
   b. magnetism, heat, and chemical reaction.
   c. heat, light, and mechanical reaction.
   d. chemical action, relative motion, and magnetic field.

Answer: 1. b; 2. c; 3. c; 4. c; 5. b.

The drift of free electrons through a conducting material is called current low. To set this stream of electrons in motion, we must have an electrical ressure which we call the electromotive force. Since an electrical current s dependent on moving electrons, any collision with other electrons or recombining with other atoms for a short period of time will tend to oppose or resist urrent flow in the conducting material. In other words, when electrons are orced through a conducting material, the friction between the electrons and toms which form the material holds back the electron flow and this restriction is called opposition to current flow.

The restriction created by the collision of electrons as they move through a conducting material is called

a. opposition to current flow.

b. movement of free electrons.

c. opposition to proton movement.

d. electromotive force.

Answer: a.

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The opposition to the flow of current offered by a conducting material is called resistance. All conducting material has a certain amount of resistance. The amount of resistance in a material depends on the number of valence electrons that can be detached from the atom and become free electrons. Materials which offer the greatest opposition to current flow are those that will not easily give up the valence electrons around its atom. We say that these materials have high resistance.

The opposition to current flow in a conducting material is known as

a. resistance.

b. electromotive force.

c. amperes.

d. reactance.

Answer: a.

The opposition of a material to a steady electron flow is called its resistance. The flow of current in a material depends upon its molecular structure and the ease with which electrons can be detached from the atom of the material. The easier it is to detach electrons from the atom, the more free electrons there are to contribute to the flow of current. The more electrons flowing the less resistance there is in the material.

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The opposition to current flow in a conducting material is known as

a. voltage.

b. reactance.

c. resistance.

d. conductance.

Answer: c.

The unit of measurement for resistance is called an ohm, and the instrument by which resistance is measured is called an ohmmeter. Just as the volt and ampere are units of measurement, the ohm is a unit of measurement for resistance. When we measure the opposition of current flow of a material, we express the results in ohms of resistance.

The unit of measure for resistance is the

a. volt.

b. ampere.

c. watt.

d. ohm.

Answer: d.

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Let us review. Experiments show that materials offer a certain opposition to the passage of an electrical current which we call resistance. It is necessary, therefore, to apply an electromotive force (voltage) at the terminals of the conducting material to produce a flow of current through it. It is found that the value of a steady current produced in a conducting material is directly proportional to the electrical pressure applied. The practical unit of resistance is called the ohm. The ohm is such that a conducting material is said to have a resistance of one ohm when an applied EMF of one volt causes a current of one ampere to flow.

The opposition to current flow in a conducting material is known as

a. conductor.

b. resistance.

c. reactance.

d. amperes.

The unit of measure for resistance is the

a. volt.

b. watt.

c. ampere.

d. ohm.

Answer: b. ; d.

The opposition to the flow of current offered by a conducting material is called resistance. Now let's talk about some of the things that affect resistance. Different materials have a different resistance to the flow of electrons. Our lesson on Atomic Structure pointed out that some materials gave up electrons easier than others. Materials such as gold, silver, copper, and aluminum which have one, two, or three valence electrons make the best conducting material. The valence electrons of these materials can be easily removed from its atom and become free electrons. If we apply an external force, we can move these electrons in a desired direction with very little opposition. Other materials, such as wood, glass, and rubber, are composed of atoms with tightly held electrons. These materials offer considerable resistance to the transfer of electrons.

One factor affecting the resistance of a material is the

a. type of material.

b. applied voltage.

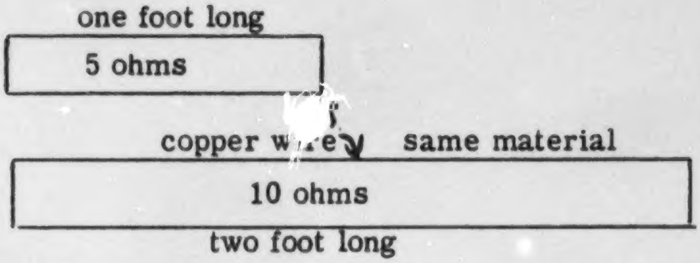
c. type of current.

d. proton movement.

Answer: a.

The type of material is probably the most important factor affecting the resistance of a material. However, there are other factors. The longer the conducting material, the higher the resistance is going to be. The resistance to moving electrons depends on the number of collisions with other electrons and atoms. Therefore, the greater the length of the material, the greater will be the number of collisions, and consequently, more resistance. If a conductor one foot long has a resistance of 5 ohms, then a conductor made of the same material two feet long would have 10 ohms resistance.

Study the illustration.



Write the name of two factors affecting resistance of a material.

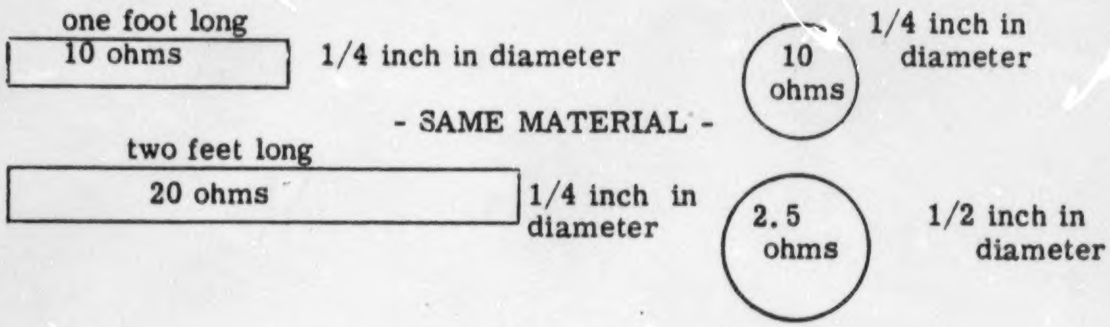
1. ____________________.

2. ____________________.

Answer:
1. Type of material
2. Length

The next factor is the cross-sectional area (how big around it is) of the material. The effect of the cross-sectional area is opposite the effect caused by the length of the material. A material one foot long and 1/4 inch in diameter has a resistance of 10 ohms. A conductor made of the same material, one foot long but 1/2 inch in diameter, would have 2.5 ohms resistance. The greater the cross-sectional area, the greater space the electrons will have to move before bumping into other electrons or atoms. Reduce the collisions between electrons and we have less resistance. The resistance of a material is directly proportional to the length and inversely proportional to the cross-sectional area.

Study the illustration.


one foot long
10 ohms
1/4 inch in diameter
10 ohms
1/4 inch in diameter
- SAME MATERIAL -
two feet long
20 ohms
1/4 inch in diameter
2.5 ohms
1/2 inch in diameter

Three factors affecting the resistance of a material are the

a. cross-sectional area, insulation, and electromotive force.

b. length, type of material, and chemical reaction.

c. temperature, voltage, and current.

d. type of material, cross-sectional area, and length.

Answer: d.

We have covered three of the factors affecting the resistance of a material. They are the type, length, and cross-sectional area of the material. The fourth and last factor is the temperature. As you apply heat to a material, movement of electrons increase. This increase in electron movement causes more collisions between the electrons and these collisions cause the resistance to increase. If current is forced through a material that offers considerable opposition to the transfer of electrons, the temperature will be high. Current flow in any conducting material will produce some heat. However, it is the increase of the external temperature that will cause the increase of resistance in a material.

The four factors affecting the resistance of a material are the

a. type of material, applied voltage, proton movement, and heat.

b. length, chemical action, current, and insulation.

c. electromotive force, temperature, cross-sectional area, and diameter.

d. type of material, cross-sectional area, length, and temperature.

Answer: d.

In order to have current flow, the electrons must have a path to move through. An electrical circuit is a closed path for the flow of electrons. The starting point is some type of device to create electromotive force, such as a battery. The circuit is not complete until the conducting path can be traced back to the starting point where the electromotive force originates. This conducting path is known as a conductor.

Match the letter of each term to the appropriate definition in the left hand column.

Definition		Term
1. A unit of measurement for Electromotive force	______	a. Volt
2. A unit of measurement for current flow	______	b. Ohm
3. A unit of measurement for resistance	______	c. Amperes
4. A path through which electrons can move	______	d. Conductor
5. Opposition to current flow	______	e. Resistance

Answers:
1. a
2. c
3. b
4. d
5. e

Now let's talk some more about the conductor. In certain materials, electrons are readily separated from the atom. The easier it is to detach electrons from the atom, the more free electrons there are to contribute to the flow of current. Experiments show that in some metals there is such a free interchange of orbital electrons between atoms that free electrons appear to exist without an outside force being applied. The metal seems full of free electrons. Such a material is used to make conductors. This type of material offers very little opposition to the movement of electrons.

Conductors are constructed from materials with

a. high resistance.

b. low resistance.

c. the ability to retain its electrons.

d. a large number of valence electrons.

Answer: b.

A conductor is constructed of material that offers small opposition to the flow of electrons. Material of this type has valence electrons that easily become free electrons when an electromotive force is applied. In contrast to good conductors, some materials are composed of atoms with tightly held valence electrons. The valence shell is almost complete, and few electrons escape to become free electrons. Such materials offer great opposition to the movement of electrons between atoms. Materials which offer the greatest resistance to current flow are used as insulators.

Conductors are constructed from materials with

(Check (✓) the correct answer)

a. tightly held valence electrons.

b. a large number of atoms.

c. high resistance.

d. low resistance.

Materials with extremely high resistance are used as

a. insulators.

b. conductors.

c. fuses.

d. ohms.

Answer: d.; a.

Now let's review the conductor - insulator area. Substances that permit the movement of a large number of free electrons are called conductors. The greater the number of electrons that can be made to move in a material under the application of a given electromotive force, the better are the conductive qualities of that material. An insulator is a substance that has few free electrons. Since current flow depends upon the movement of free electrons, the lack of free electrons in an insulator will prevent the flow of current. The insulation on the electrical wiring prevents the current from jumping to other devices or being knocked into space.

Check (✓) the correct answer

Conductors are constructed from materials with a large number of

a. molecules.

b. atoms.

c. protons.

d. free electrons.

Materials having very few free electrons make good

a. atoms.

b. conductors.

c. molecules.

d. insulators.

Answer: d.; d.

We said that a good conductor is a material that offers small opposition to the flow of electrons (current). Actually, what we are saying is that a good conductor will readily accept or give up its valence electrons. Thus, a very small force or amount of energy (electromotive force) will cause such electrons to be moved from the atom and become free electrons to contribute to the flow of current. Some of the materials that will do this for us are copper, aluminum, iron, platinum, and silver. In general all metals are good conductors.

Check (✓) the true statements.

☐ 1. A good conductor will be made from copper, aluminum, iron, silver, and platinum.

☐ 2. Metals can be used as conductors or as insulators.

☐ 3. A good conductor will readily accept or give up its valence electrons.

☐ 4. A good conductor has atoms which provide very few free electrons.

☐ 5. Copper, aluminum, iron, silver, and platinum are used as conductors because their atoms readily accept or give up valence electrons.

Answer: 1, 3, 5.

We said that an insulator is a material that offers great opposition to the movement of electrons. An insulator has electrons just as all materials have, but it has practically no free electrons. The valence electrons have combined with other valence electrons to complete the valence shell, leaving no free electrons available for current flow. Rubber, glass, paper, dry air, mica, and bakelite are examples of good insulating materials.

Check (√) the correct answer.

☐ 1. Insulators are made of materials that offer very little opposition to current flow.

☐ 2. Conductors are made of materials that offer great opposition to the movement of electrons.

☐ 3. A good conductor will be made from copper, aluminum, iron, silver, and platinum.

☐ 4. A good insulator will be made from rubber, paper, dry air, glass, bakelite, and mica.

Answer: 3, 4.

It is incorrect to say that all materials are either conductors or insulators, because there is no sharp dividing line. The best conductors are used to carry current, and the poorest conductors are used as insulators to prevent current flow. All substance offers some opposition to current flow. This opposition is called resistance. Insulators have great resistance, while conductors have little resistance. The best insulators - that is, the poorest conductors, are rubber, glass, paper, dry air, gas, mica, and bakelite. The best conductors are the metals and acids.

Identify the materials that are used as insulators and the materials used as conductors by placing an "I" or "C" in the appropriate blank.

Rubber ____

Glass ____

Paper ____

Copper ____

Aluminum ____

Dry air ____

Mica ____

Iron ____

Platinum ____

Silver ____

Bakelite ____

Gas ____

Materials with extremely high resistance are used as

a. conductors.

b. fuses.

c. ohms.

d. insulators.

Conductors are constructed from material with

a. tightly held valence electrons.

b. a large number of atoms.

c. high resistance.

d. low resistance.

Answer: I, I, I, C, C, I, I, C, C, C, I, I; d. d.

Let's review the information on resistance and the factors affecting resistance. A copper wire will conduct current with relative ease, but it still offers some resistance to current flow. The amount of resistance in wires will vary with the diameter, length, temperature, and the type of material. A large diameter wire offers less resistance than a small diameter wire. Iron wire has fewer free electrons than copper wire. Therefore, iron wire offers more resistance than a copper wire of the same temperature, length, and diameter. The resistance of most metals increases with an increase in temperature.

Check (✓) the correct answers.

The opposition to current flow in a conductor is known as

a. reactance.

b. resistance.

c. voltage.

d. reluctance.

The unit of measure for resistance is the

a. henry.

b. watt.

c. ohm.

d. ampere.

The four factors affecting the resistance of a material are the

a. length, temperature, voltage, and insulator.

b. temperature, cross-sectional area, insulator, and type of material.

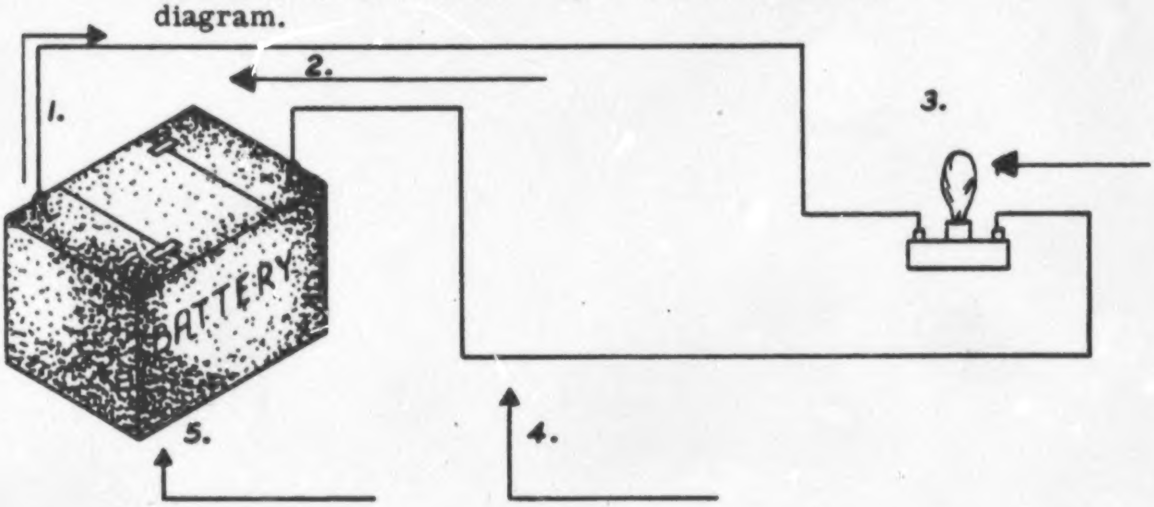
c. chemical structure, insulator, number of protons, and length.

d. type of material, length, temperature, and cross-sectional area.

Answer: b; c; d.

By now you should be familiar with the terms - electromotive force which is measured in volts, current which is measured in amperes, and resistance which is measured in ohms. When we speak of electromotive force, we will call it voltage. Voltage by itself does not contain energy, and voltage by itself can do no work. The same is true of current alone. To transmit energy and to do work, voltage and current must act together. If voltage and current are to act together, there must be a conductor for the current to move through, and some device to be acted upon. The conductor must start at the source of voltage, go to the device acted upon, and return to the source of voltage. We have described what is called an electrical circuit.

Use the words conductor, voltage, device acted upon, current, and resistance - label each arrow on the diagram.



Answer: 1. current; 2. resistance; 3. device acted upon;
4. conductor; 5. voltage.

Now let's discuss the effects of current flow on the circuit and electrical devices. One effect of current flow is heat. The heating effect of current is produced when electrons are forced to move in a material which has high resistance. The movement of electrons in high resistance material produces high internal friction and results in the production of heat. The filament in lamp bulbs has such high resistance that when electrons move through this filament it heats to a white hot condition and gives off light. Current flow in any conductor will produce some heat, but to take advantage of the heating effect, high resistance materials are used. This heating effect is used in many places including electric stoves, heating pads, soldering irons, etc.

The product of heat in a resistor is the effect of

a. low voltage.

b. resistance.

c. chemical reaction.

d. current flow.

Answer: d

Current produces chemical action when it flows through a liquid. Example of this effect are the charging of a battery. The chemical reaction causes the acid to remove electrons from one plate and store them on the other plate. When an outside circuit is connected between the terminals of the plate, a current will flow until the solution of acid is neutralized by the materials of the battery plate. In this state, the battery is completely discharged and will not produce electromotive force. If a current is forced through the battery in an opposite direction, the chemical effect of the current will separate the acid elements from the plate material. The battery will be restored to its former charged condition. Other uses of the chemical effects of current flow include electroplating of metals, and commercial production of hydrogen, oxygen, and chlorine gases.

Two effects caused by current flow are

a. chemical reaction and current.

b. heat and electromotive force.

c. voltage and resistance.

d. chemical reaction and heat.

Answer: d

The magnetic effect of current flow gives us the operation of telephones, telegraph, lifting magnets, electrical meters, motors, and transformers. This is perhaps the most used of the various effects of current flow. When current flows through a wire, a magnetic field is set up around the wire. The direction and strength of the magnetic field will be determined by the direction and strength of the current producing it. The magnetic field around a current carrying wire is composed of circular lines of magnetic force. As you know, electromotive force is produced by rotating a conductor through the field of force. The above named devices also operate in a similar manner because of the magnetic effect caused by current flow.

The product of heat, chemical reaction, and magnetism in conductors or liquids is the effect of

a. induced reaction.

b. induced resistance.

c. insulator.

d. current flow.

Answer: d

The shock effect of current is a very undesirable effect. This shock is caused by the passage of current through the body or a portion of the body and is caused by contact with a current-carrying conductor. The results are burns and a paralyzing effect on the heart and chest muscles. A current of only a fraction of an ampere flowing through the human body is usually fatal.

The product of heat, chemical action, magnetism, and electrical shock in a conductor or liquid is the effect of

a. ohms.

b. potential voltage.

c. resistance.

d. current flow.

Just one more word on current and you are through with the subject.

Current which flows steadily in the same direction such as the current flow caused by a battery is called direct current, and is abbreviated as DC. The current used in most appliances in your home, such as irons, lights or refrigerators, does not flow steadily in the same direction but flows first in one direction and then in the opposite direction at regular intervals. It is produced by the magnetic field of a generator. This kind of current is called alternating current, and it is abbreviated as AC.

Answer: d

CRITERION EXAMINATION

> If you miss more than 3 out of the 33 total responses, you have not satisfactorily completed the assignment.

1. Match the definitions with the list of terms by placing the number of the definition in the appropriate blank.

Matter ____

Molecule ____

Atom ____

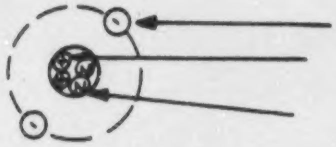
Element ____

Compound ____

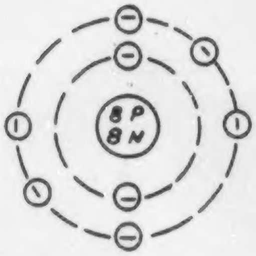
1. The smallest particle of an element that can take part in ordinary chemical change.
2. A substance which is made up of different kinds of atoms in chemical combinations.
3. A substance which is made up of the same kind of atoms.
4. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance.
5. Anything which occupies space and has weight.

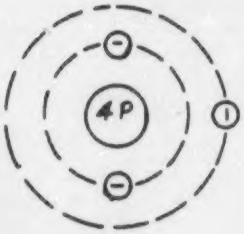
2. Identify the components of the illustrated atom by placing the number of the component in the appropriate blank.

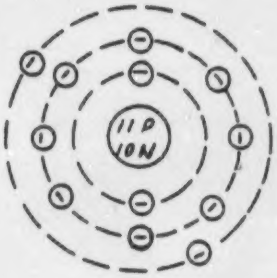
   1. Electron
   2. Nucleus
   3. Neutron
   4. Ion
   5. Proton



3. Identify the electrical charge of each illustrated atom by writing the word Positive, Negative,or Neutral in the appropriate blank.







4. The definition of electrical current is the

   a. flow of applied voltage through a conducting material.

   b. movement of free electrons through a conducting material.

   c. flow of magnetic flux around a conducting material.

   d. result of ohms through a resistive material.

5. The unit of measure for current flow is the

   a. volt.

   b. Ohm.

   c. proton.

   d. ampere.

6. The product of heat, chemical change, electrical shock,or magnetism in conductors or liquids is the effect of

   a. potential voltage.

   b. current flow.

   c. resistance.

   d. power potential.

7. The electrical pressure that causes current flow through a conductor is called

   a. electromotive force.

   b. henrys.

   c. chemical reaction.

   d. induced reaction.

8. The unit of measurement for electromotive force is the

   a. watt.

   b. ampere.

   c. ohm.

   d. volt.

9. The three sources of electromotive force are

   a. chemical reaction, heat, and magnetism.

   b. current, voltage, and resistance.

   c. inductive reaction, chemical reaction, and heat reaction.

   d. chemical reaction, heat, and current.

10. The opposition to current flow in a DC circuit is known as

    a. reactance.

    b. resistance.

    c. voltage drop.

    d. reluctance.

11. The unit of measure for resistance is the

    a. henry.

    b. watt.

    c. ohm.

    d. ampere.

12. The four factors affecting the resistance of a material are the

    a. length, temperature, cross sectional area, and relative resistance.

    b. temperature, length, cross sectional area, and the insulation.

    c. cross sectional area, insulation, chemical structure, and temperature.

    d. type of material, length, temperature, and cross sectional area.

13. Materials with extremely high resistance are used as

    a. insulators.

    b. conductors.

    c. fuses.

    d. resistors.

14. Conductors are constructed from materials with

    a. high resistance.

    b. low resistance.

    c. low permeability.

    d. high permeability.

15. Identify the materials that are used as insulators and the materials used as conductors by placing an "I" or "C" in the appropriate blank.

Rubber ____
Glass ____
Paper ____
Copper ____
Aluminum ____
Dry air ____
Mica ____
Iron ____
Platinum ____
Silver ____
Bakelite ____